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4 April 1988

MEMORANDUM

TO: Dinesh Gupta and Jaak Daemen

FROM: Loren Lorig

RE: Final CDSCP Point Papers

Included with this memo are my thoughts about possible changes to the final CDSCP point papers in the area of rock mechanics/ design. My suggestions are based on comments made at the 21 March meeting with DOE and on internal discussions prior to the meeting.

Comment 103, concerning performance confirmation, is left unchanged. DOE suggested that Section 8.2.2.1.1.7 describes their performance confirmation program and gives a rationale for developing the program during the testing period. Perhaps we should discuss this.

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Comment 1

Consider eliminating or replacing the first item under the second "bullet" of BASIS with the following.

> The testing plan does not describe in-situ testing aimed at providing a complete set of joint properties needed as input to design and performance assessment models. Design and performance assessment models require descriptions of joint normal stiffness, shear stiffness, friction and dilation as functions of shear displacement, normal stress and temperature, among other things. Only the large rock mass strength experiment (p. 8.3.1.15-64) discusses in-situ testing of joints. However, this testing is apparently limited to determination of ambient temperature shear strength properties. [The Yucca Mountain heated block test (pp. 8.3.1.15-53 to -58) presumably will not provide information about shear behavior of joints because blocks tests are typically designed so that shear failure of joints is minimized.] Empirical joint constitutive models, such as the one described for the compliant joint model, may be used to describe in-situ behavior of joints. However, no specific testing is identified which is aimed at validating joint models.

Comment 29

Rewrite the first sentence of the comment as follows.

> The CDSCP's approach to characterizing the complex three-dimensional nature of fracture systems in the repository block relies on fractal analysis of outcrop exposures and geologic mapping of ES-1, drifts and boreholes (excluding floors and working faces).

Rewrite the first sentence of the second "bullet" under BASIS as follows.

> Three-dimensional descriptions of fracture systems can be evaluated by systematic mapping of FS-1 and drifts, including mapping of some reaches of shaft floor and drift faces.

SECTION 8.3.1.15 — OVERVIEW OF THERMAL AND MECHANICAL ROCK PROPERTIES (pp. 8.3.1.15-1 through -14)

Comment 43/44

The testing rationale and testing program described in Section 8.3.1.15 may be deficient in some respects. Some of the tests are defined in a limited manner so that it is difficult to determine what or how specific information is to be obtained.

BASIS

- The CDSCP attempts to show the integration of the thermal and mechanical properties evaluations by relating the particular property to be measured to a specific information need (Table 8.3.1.15-1). However, it does not give adequate rationale for information presented in this table. The parameters to be measured, the confidence required, and number of tests need to be based on analysis of the performance of the selected repository design. The NRC GTP on In-Situ Testing During Site Characterization places particular emphasis on the need to provide a rationale for the in-situ testing (NRC, 1985, Section 5.2).

- Each parameter to be measured is assigned a needed confidence level and an SCP activity number in Table 8.3.1.15-1. However, the test methods discussed for each activity number do not reflect or discuss procedures aimed at achieving a specified confidence level.

- CDSCP Chapter 6 discusses several potential constitutive models (equivalent elastic, ubiquitous joint, compliant joint) to be used for design analysis and performance assessment. However, the strategy for using models to design tests, evaluate results, validate important aspects of the models, and select appropriate model(s) for use in design is not presented.

- The full-scale heater test apparently will not be used to determine the ultimate loading (i.e., temperature and thermally-induced stress) potential of the boreholes. This test could be used to verify the retrieval concepts and performance measures discussed in Section 8.3.5.2. There is no discussion of the need for assessing design criteria such as pressures on liners, curvature of holes in vertical or horizontal configurations, etc., as set forth in Section 8.3.5.2.

- The "strength" of the rock mass is to be determined by an ill-defined test. A definition of the term "strength" is necessary because many interpretations are possible, each one requiring different parameters. The "strength" test should be developed using models to evaluate the validity of the basic constitutive laws presently considered for tuff.

- Plate-bearing tests may yield a much stiffer response than expected due to directional loading effects (not necessarily a lower bound as implied in the text, p. 8.3.1.15-62).

- None of the potential difficulties or possible alternatives are described in this plan—e.g., the G-Tunnel heated block was plagued by horizontal fracture propagation in the block due to lack of vertical confinement which may have affected results (Reference 2).

RECOMMENDATION

- The testing program for thermal and mechanical rock properties presented in the SCP should clearly identify and define all the required parameters that can be obtained by the tests and recognize potential difficulties that may prevent the tests from obtaining those parameters. Alternate tests should be proposed as backups in cases where a parameter may not be obtainable by the test initially proposed.

- It is recommended that a testing rationale and performance calculations, aimed at demonstrating how the test program will meet the License Application information needs, be included or referenced in the SCP.

REFERENCE

1. NRC, 1985. GTP on In Situ Testing During Site Characterization for High-Level Nuclear Waste Repositories.

2. Zimmerman, R., et al. "Final Report: G-Tunnel Heated Block Experiment," SAND84-2620.

Comment 45

Replace the BASIS with the following.

- The statement "It is these latter two parameters that are needed when determining whether tolerance limits specified by performance and design issues are being met." (p. 8.3.1.15-23) implies that μ and σ are the only two required quantities. However, geologic parameters are spatially correlated. As such, μ and σ are not sufficient to develop tolerance limits (regardless of the distributional model assumed).

- Clearly, "x-bar" and "s" can be calculated for any list of numbers. The calculation requires nothing more than simple arithmetic. However, the proposed method of accounting for the uncertainty described on p. 8.3.1.15-23 assumes that the samples were collected from independent, identically distributed, normal random variables. These are three unsupported (unsupportable) assumptions.

- The assumption of normality (i.e., normal distribution), even if it is a correct assumption, does not justify the use of "x-bar" and "s" in a spatially-correlated geologic setting. Furthermore, in a geologic (and particularly in a geotechnical) environment, the "normal" distribution is the rare exception rather than the rule.

- The selection of "α" and "γ" for use in tolerance interval-based sampling design is a critically important issue. Relatively small changes in the "α" and "γ" values can bring about an order of magnitude change in the required sample size. This should not be an issue of "convenience" (p. 8.3.1.15-23).

- The definitions of "high confidence" as "$\alpha = 0.05$", "medium confidence" as "$\alpha = 0.10$", and "low confidence" as "$\alpha = 0.25$" appear to be arbitrary.

- The implication in the example describing the number of samples to calculate vertical in-situ stress (p. 8.3.1.15-24) is that there is only one value for the in-situ vertical stress throughout the entire geologic unit. Also, the fact that geologic samples are spatially correlated is ignored. For example, 22 measurements taken from the same location will not adequately characterize the in-situ vertical stress in unit TSw2.

- The statement "No a priori assumptions have been made either about spatial variability of a parameter . . . ." (p. 8.3.1.15-24) is incorrect, because the proposed method assumes that the samples are spatially uncorrelated.

- Geologic parameters are not homogeneous on the scale of the repository. That is, the geologic parameters are guaranteed to change from location to location. The critical issue is not determining whether spatial variation exists for the geologic parameters; rather, the concern is to quantify (characterize) the spatial variation and to assess the impact of spatial variation on the design, construction, and operation of the repository. Replicate sampling at "each selected spatial location" does not address this issue. Replicate sampling to characterize measurement error and to assess the potential for measurement bias is valuable.

- Setting the required number of samples to "high = 40", "medium = 20", and "low = 10" (p. 8.3.1.15-24) is arbitrary, and it reduces the credibility of the quasi-statistical presentation.

Comment 48

Delete the comment or modify as follows.

Plate-load tests do not necessarily provide an accurate means of determining rock mass deformational properties. Data obtained from such tests may be useful in assessing spatial variability, effects of different excavation procedures, etc. as part of the overall program to characterize rock mass deformational relations.

BASIS

- The analysis of plate-loading tests normally assumes that the rock mass properties are isotropic in nature; however, because of the influence of fracturing, the rock mass may not exhibit isotropic deformation properties. Therefore, calculation of response with a single extensometer may be misleading. The conduct of multiple plate-loading tests may provide a false statistical importance. Also, the test only determines the characteristics of the fractured skin of the opening.

RECOMMENDATION

- The SCP should describe and justify the applicability of data from the activity proposed in Section 8.3.1.15.1.7.1 of the CDSCP as a suitable means of providing deformation properties to models. The SCP should examine potential problems in interpretation of the test due to the influence of joint structure on anisotropy of response.
- The SCP should discuss how results of the plate-load tests will be integrated into the overall program aimed at characterizing rock mass deformational relations and model validation.

SECTION 8.3.2.1.4.1.1 — GEOMECHANICAL ANALYSES (p. 8.3.2.1-21)

Comment 54

Replace the first two sentences and the BASIS with the following.

> The CDSCP has limited its consideration of how jointed tuff can be treated to equivalent continuum models. A brief description of each of the models is given in Chapter 2 (pp. 2-19 and -20). Consideration of only equivalent continuum models may be too restrictive.
>
> BASIS
>
> The analysis program appears to be heavily reliant on the development of an equivalent continuum model to characterize the tuff. However, little justification has been presented for the choice of equivalent continuum models in the analyses to date. The usual justifications given are the simplification of the behavior and the reduction in the number of parameters to be specified.
>
> Such material models may be misleadingly simple and miss essential behavior features even if one or two calculated results match. For example, equivalent continuum models will do an excellent job of representing the behavior of a block of jointed rock subject to uniform stress boundary conditions but may not do nearly as well when stress gradients are introduced. If validation testing does not include tests with a stress gradient boundary condition, then an important deformation mechanism may be overlooked.
>
> Another limitation of equivalent continuum material models concerns the issue of intersecting joints. Equivalent continuum models must either be restricted to slip motion on a particular joint set or assume very small joint spacing. The reason for this can be understood by considering a rock mass cut by two intersecting joint sets.

Relative movement on one joint set produces a stepped surface on the second set. The shear strength is then a function of applied shear direction. Note that initial shearing does not involve dilation but subsequent shearing does. Most current continuum models do not adequately account for this behavior.

The preceding illustrates that there are complex mechanisms involved in the response of jointed rock which equivalent continuum models can easily miss.

Other models, such as quasi-discrete or distinct element models, may be equally valid. For example, the CDSCP acknowledges that equivalent continuum models do not address block failure and that distinct element models may be required (p. 8.3.2.2-82). Blanford and Key (1987) demonstrated that a quasi-discrete approach of isolating joints from the rock matrix can be appropriate, particularly near areas of high stress gradient.

<u>Comment 55</u>

Eliminate the comment or replace with the following.

Geomechanical analyses in this section do not consider the effects of emplaced support components or the effect of elevated temperature on the support system components. System element 1.2.1.2, drift construction, recognizes the need for designing ground support to accommodate the long-term (i.e., thermal) considerations. However, consideration thermal effects is limited to consideration of thermally-induced stresses in the rock mass, not support components.

Comment 57

Delete the comment or modify as follows.

The CDSCP states that the potential for the development of new paths to the accessible environment or for an extension of the disturbed zone will be mitigated by backfilling the emplacement drifts. Given the proposed loose backfill and only partial filling of drifts, this effect may be quite limited. No testing is described to either directly assess the mitigating affects of backfill or provide information to be used in numerical models capable of representing backfill.

BASIS

- Backfill design presently allows a 1 to 5 ft void between backfill and roof (Section 5.1.2.2, p. 5-3). Hence, considerable rock fall can take place, with creation of voids above the drifts, before the backfill can resist the rock mass displacements.

RECOMMENDATION

- If a mechanical function is to be assigned to the backfill, it is recommended that the function be designed on the basis of field tests or a comprehensive and realistic mechanical analysis of drift-backfill interaction, backfill compaction characteristics, and initial compaction density.

Comment 68

Consider adding the following to the end of the comment.

> Table 3-2 of Fernandez et al. (1987) compares the maximum-allowable performance goals and design-basis performance goals. In the period from 1,000 to 10,000 years following repository closure, the ratio of "maximum allowable" to "design-basis" decreases from 2.8 to 1.0.

Comment 70

Provide complete reference to Fernandez et al. (1987):

> Fernandez et al., 1987. Technical Basis for Performance Goals, Design Requirements and Material Recommendations for the NNWSI Repository Sealing Program, SAND84-1895, Sandia National Laboratories, Albuquerque, New Mexico.

Comment 98

Delete the last "bullet" under BASIS.

Question 16

The section number given in the question should be 8.3.1.4.2.2.3, not 8.4.1.4.2.2.3.

Question 34

Consider rewriting the question as follows.

> Why is there no link (other than that indicated in Fig. 8.3.2.1-1) established between this plan and Issue 1.12 — Repository Sealing?

THIS PAGE IS AN OVERSIZED DRAWING OR FIGURE,

THAT CAN BE VIEWED AT THE RECORD TITLED:
NEW HAMPSHIRE YANKEE SEABROOK STATION, FIGURE 6-1, MASSACHUSETTS SIREN SYSTEM COVERAGE.

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