Department of Energy
Washington, DC 20585

SEP 2 1993

Mr. Joseph J. Holonich, Director
Repository Licensing & Quality Assurance
Project Directorate
Division of High-Level Waste Management
Office of Nuclear Material Safety and
Safeguards
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Holonich:

Enclosed are the U.S. Department of Energy's (DOE) responses to four questions on Study Plan 8.3.4.2.4.3 (Characterization of Mechanical Attributes of the Waste Package Environment) received from the U.S. Nuclear Regulatory Commission (NRC) on April 21, 1993 (enclosure 1). These questions were forwarded to the responsible principal investigator at Lawrence Livermore National Laboratory for responses.

The changes identified in the responses (enclosure 2) will be made in a subsequent revision to the study plan. This revision will be undertaken in the future in order to incorporate the results of ongoing thermal loading and waste package emplacement system studies.

If you have any questions, please contact Ms. Sheila Long at 202-586-1447.

Sincerely,

Dwight E. Shelor
Associate Director for
Systems and Compliance
Office of Civilian Radioactive
Waste Management

Enclosures:
1. Ltr, 4/21/93, Holonich to Shelor
2. Responses to NRC Questions

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

APR 2 1 1993

Mr. Dwight E. Shelor, Associate Director
for Systems and Compliance
Office of Civilian Radioactive Waste Management
U. S. Department of Energy
1000 Independence Avenue, SW
Washington, D. C. 20585

Dear Mr. Shelor:

SUBJECT: REVIEW OF U.S. DEPARTMENT OF ENERGY STUDY PLAN "CHARACTERIZATION OF THE GEOMECHANICAL ATTRIBUTES OF THE WASTE PACKAGE ENVIRONMENT"

On December 24, 1992, the U.S. Department of Energy (DOE) transmitted the study plan, "Characterization of the Geomechanical Attributes of the Waste Package Environment" (Study Plan 8.3.4.2.4.3) to the Nuclear Regulatory Commission for review and comment. NRC has completed its review of this document using the Review Plan for NRC Staff Review of DOE Study Plans, Revision 2 (March 10, 1993). The material submitted in the study plan was considered to be consistent, to the extent possible at this time, with the revised NRC-DOE "Level of Detail Agreement and Review Process for Study Plans" (Shelor to Holonich, March 22, 1993).

A major purpose of the review is to identify concerns with studies, tests, or analyses that, if started, could cause significant and irreparable adverse effects on the site, the site characterization program, or the eventual usability of the data for licensing. Such concerns would constitute objections, as that term has been used in earlier NRC staff reviews of DOE's documents related to site characterization (Consultation Draft Site Characterization Plan and the Site Characterization Plan for the Yucca Mountain site). It does not appear that the conduct of the activities described in this study plan will have adverse impacts on repository performance and the review of this study plan identified no objections with any of the activities proposed.

In a March 4, 1993, conference call with representatives of DOE and the State of Nevada, the staff raised an integration problem related to activities described in this study plan and Study Plan 8.3.1.4.1.1. The subject study plan referred to rock samples for testing that were to be obtained from work performed under Study Plan 8.3.1.4.1.1. However, Study Plan 8.3.1.4.1.1 does not identify that commitment. In the March 1993 conference call DOE agreed to revise Study Plan 8.3.1.4.1.1 to reflect sample collection for tests described under the subject study plan (8.3.4.2.4.3). The NRC staff has deferred its review of Study Plan 8.3.1.4.1.1 pending receipt of that revision.

As part of its study plan review, the NRC staff determines whether or not detailed comments or questions are warranted. The NRC staff's review of the subject study plan has resulted in the identification of four questions (Enclosure 1). The enclosed questions will be tracked by the NRC staff as open items similar to Site Characterization Analysis (SCA) comments and questions.

Based on information provided by DOE in its letter transmitting this study plan, the staff has determined that SCA Question 17 should be considered resolved. The staff's evaluation of that information is in Enclosure 2 to this letter.

If you have any questions concerning this letter, please contact Charlotte Abrams (301) 504-3403 of my staff.

Sincerely,

Joseph J. Holonich, Director
Repository Licensing and Quality Assurance
Project Directorate
Division of High-Level Waste Management
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Enclosures: As stated

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Enclosure 1

STUDY PLAN 8.3.4.2.4.3 - CHARACTERIZATION OF THE GEOMECHANICAL ATTRIBUTES OF THE WASTE PACKAGE ENVIRONMENT

QUESTION 1

The DOE has recently described various alternative thermal loading strategies and waste package emplacement schemes in presentations. What alternative tests are being considered by DOE to correspond with those proposed thermal loading strategies and waste package emplacement schemes?

BASIS

DOE described various thermal loading strategies to the Nuclear Waste Technical Review Board (NWTRB, 1992); although, the evaluation of the technical merits and uncertainties of various thermal loading strategies has not yet been performed. If DOE decides to choose a higher thermal loading for the repository design, the maximum wall rock temperature would be substantially higher than the current 275°C design level. Therefore, the proposed 300°C thermal range of laboratory experiments of the current study plan may need to be revised.

DOE also described to the NWTRB a scheme for horizontal room-emplacement of waste packages (Stahl, 1992). Authors of this study plan anticipate that it will be revised to incorporate future changes in the waste package (WP) design, but the impact on this study plan from changes to the WP design has not been addressed. For example, if the horizontal emplacement scheme is adopted, then the vertical borehole damage study may not be meaningful.

RECOMMENDATION

In revisions to the study plan and in its semi-annual progress reports, DOE should describe its alternatives for the thermal loading strategy and waste package emplacement scheme. The potential impact of these alternative strategies on the current planned laboratory experiments should also be addressed.

REFERENCES

NWTRB, 1992, Fifth report to the U.S. Congress and the U.S. Secretary of Energy: Nuclear Waste Technical Review Board, June, 1992.

Stahl, D., 1992, Source term concept and definition: Presentation to the Nuclear Waste Technical Review Board, October 14-16, Las Vegas, NV: Waste Package Performance Analysis Management and Operating Contractor, 1992.

STUDY PLAN 8.3.4.2.4.3 - CHARACTERIZATION OF THE GEOMECHANICAL ATTRIBUTES OF THE WASTE PACKAGE ENVIRONMENT

QUESTION 2

Will additional activities described in Section 1.4, Future Studies (page 1-16) include the seismic loading study? Section 1.4 states that "additional activities are anticipated, which are still to be developed." What is the relationship between these additional, undeveloped ESF field studies and the planned ESF field thermal and mechanical testing activities described in the SCP?

BASIS

The study of seismic loading impact is mentioned in Sections 2.0, Rationale for Selected Study, and 2.1.1, Rationale for Block Stability Analysis, of the study plan. The study plan states that additional activities are anticipated, but are not yet developed. There is no discussion of seismic loading in the future studies section. It is unclear whether the seismic loading study will be included in the studies to be conducted in the future.

The study plan mentions that the anticipated additional studies will include both field studies conducted in the ESF and studies of natural analogues. The relationship between the additional ESF field studies described in this study plan and the planned ESF field thermal and mechanical testing activities described in the SCP is unclear.

RECOMMENDATION

Activities related to seismic loading considerations and additional field tests should be described in revisions to the study plan. If new field tests will be conducted in addition to the SCP planned ESF field tests, the rationale for those new field activities should be stated clearly.

STUDY PLAN 8.3.4.2.4.3 - CHARACTERIZATION OF THE GEOMECHANICAL ATTRIBUTES OF THE WASTE PACKAGE ENVIRONMENT

QUESTION 3

What potential impacts from nonavailability of data from other studies and ESF validation experiments have been considered? Would the data from this study be sufficient to validate the numerical codes?

BASIS

The ESF thermal and mechanical tests related to this study plan will be performed in accordance with the following Site Characterization Plan (SCP) Sections: Excavation Investigations (8.3.1.15.1.5), In Situ Thermomechanical Properties (8.3.1.15.1.6), In Situ Mechanical Properties (8.3.1.15.1.7), and In Situ Design Verification (8.3.1.15.1.8). A large amount of field data will be collected during ESF site characterization activities. However, the availability and sufficiency of these field data for validation were not mentioned in this study plan.

Successful numerical code development requires validation using laboratory and field data. The study plan states that "verification and validation of numerical codes and use of the validated codes to estimate geomechanical properties of the near-field environment depends on the availability of qualified data from this and other studies and on the availability of the ESF for a series of validation experiments (page 2-26). However, details of the other studies and ESF validation experiments will be discussed in future revision of this study plan. It is unclear that the activities described in this study plan will produce enough data for numerical code validation in the event that the data from other studies or ESF validation experiments are not available.

RECOMMENDATION

The thermomechanical data from ESF in situ tests should be considered in validating the numerical codes. Consideration should be given to establishing a minimum cut-off for the amount of data required and alternative approaches to validate the numerical codes if data from other studies or additional activities stated in this study plan are not available. If additional data are required for the model validation, DOE should address what additional tests will be required for validation of the numerical codes.

STUDY PLAN 8.3.4.2.4.3 - CHARACTERIZATION OF THE GEOMECHANICAL ATTRIBUTES OF THE WASTE PACKAGE ENVIRONMENT

QUESTION 4

What method will be used to predict the long-term thermomechanical responses of field borehole damage and long-term radiation effects from laboratory scale rock samples and short-term radiation experiments?

BASIS

The worst-case scenario combination of the in situ stress field and thermal loading effect will cause 38% of boreholes to be damaged, according to Kemeny and Cook's study (1990). The in situ field stresses will play an important role in the borehole damage analysis. The in situ stress ratios of vertical, maximum horizontal, and minimum horizontal stresses are approximately 3:2:1 in the repository horizon (DOE, 1991, at depths 433.4 and 481.4 m). The combination of in situ stresses, excavation effect, and thermal loading will take many years to create the stress field change and cause borehole failure.

In order to conduct a short-term laboratory test to examine the long-term borehole stability, excessive differential stresses and/or higher temperature will be necessary. It is unclear what stress ratios and temperature will be applied in the true triaxial block experiments and what approach will be taken to reproduce the long-term field stress conditions in a short-term laboratory experiment.

The irradiated rock samples will be tested in the laboratory to investigate the radiation effect on rock mechanical properties. The study plan does not address the maximum dose of gamma radiation and the length of radiation period on the rock samples. The study plan also has not explained the long-term (WP emplacement scale) versus short-term (laboratory scale) radiation effect on the rock mechanical properties. It is unclear what consideration will be given to the influence of time and scale on the effect of radiation on rock.

RECOMMENDATION

Revisions to the study plan should include a discussion of the stress ratio and temperature required in a short-term test to simulate the borehole damage. Scale effect of the field rock mass versus laboratory rock samples also needs to be discussed. Simulating long-term radiation effects in a short-term test should be explained.

REFERENCES

DOE, 1991, The Yucca Mountain Site Characterization Project, Reference Information Base, Version 4, Revision 4," OCRWM, U.S. Department of Energy, 04/08/91.

Kemeny, J., and Cook, N., 1990, Rock mechanics and crustal stress, in McGuire, R.K., ed., Demonstration of a Risk-Based Approach to High-Level Waste Repository Evaluation: EPRI NP-7507, Electrical Power Research Institute, Palo Alto, CA. NNA.910813.0004, 1990.

Section 8.3.1.15 Performance and design parameters, tentative goals, and characterization parameters for thermal and mechanical properties program, Table 8.3.1.5-1, pp. 8.3.1.15-2/13

SCA QUESTION 17

What activities are planned to investigate the effects of radiation on thermal and mechanical rock properties?

EVALUATION OF DOE RESPONSE

- In response to SCA Question 17 on Site Characterization Plan Section 8.3.1.15, DOE incorporated the investigation of radiation effects on thermal and mechanical properties of repository horizon in this study plan.

- Rock samples will be irradiated in a ^{60}Co irradiation pool. The total dose of gamma radiation on rock samples will be monitored using radiochromic film.

- The irradiated and non-irradiated rock samples will be tested either in an elevated temperature enclosure or triaxial chamber with heaters to compare the radiation effect on rock thermal and mechanical properties. The radiation dependent tests are discussed in Sections 3.3.1 and 3.3.2 of this study plan.

- Based on the above evaluation, NRC staff is satisfied with the DOE's response to SCA Question 17. The NRC staff considers this question resolved.

U. S. DEPARTMENT OF ENERGY (DOE) RESPONSES TO
U.S. NUCLEAR REGULATORY COMMISSION (NRC)
DETAILED TECHNICAL COMMENTS ON STUDY PLAN 8.3.4.2.4.3,
(CHARACTERIZATION OF THE MECHANICAL ATTRIBUTES OF THE WASTE
PACKAGE ENVIRONMENT)

NRC Question 1:

The DOE has recently described various alternative thermal loading strategies and waste package emplacement schemes. What alternative tests are being considered by DOE to correspond with those proposed thermal loading strategies and waste package emplacement schemes?

DOE Response to NRC Question 1:

This question asks if and how studies conducted under this study plan will be modified to accommodate proposed changes in the strategy for thermal loading of the potential repository. Thermal loading and waste emplacement system studies are indeed underway, and interim products from these continuing studies will be available. Currently, the study plan calls for experiments on rock samples to be conducted at temperatures to 250°C. An alternative thermal loading strategy under study may call for temperatures in the near-field to reach 300°C. It is important to note that the Site Characterization Plan's (SCP) target of 57 kw/acre is still the program baseline unless or until it is changed by the project's change control process.

The DOE recognizes this concern and has written the study plan to be as general as possible. Moreover, while DOE recognizes that the repository design is not yet finalized, the study plan was written using the SCP reference design as the planning basis. DOE recognizes that the design of the repository may evolve with time and that revision of this and other study plans may be required to include activities necessary for a particular design, or to delete activities that become unneeded.

The DOE plans to revise Study Plan 8.3.4.2.4.3 in fiscal year (FY) 95. At that time, this study plan will be modified as necessary to conform to any changes in project thermal loading strategy and waste package emplacement mode. The revision will include reevaluation of the planned activities. If an alternative emplacement scheme is to be evaluated as part of the study, then the borehole damage activity may be de-emphasized and the block stability activity may be enhanced. Also, temperature ranges for the experiments and studies will be adjusted to reflect those relevant to the thermal scheme being evaluated, and additional activities will be added as necessary (e.g., evaluation of seismic loading and description of field studies as mentioned in Question 2).

NRC Question 2:

Will additional activities described in Section 1.4, Future Studies (pages 1-16) include the seismic loading study? Section 1.4 states that "additional activities are anticipated, which are still to be developed." What is the relationship between these additional undeveloped ESF field studies and the planned ESF field thermal and mechanical testing activities described in the SCP?

DOE Response to NRC Question 2:

The DOE is currently developing studies to be conducted under this study plan. These studies are being designed in concert with planning for near-field geochemistry (Study Plan 8.3.4.2.4.1), hydrology (8.3.4.2.4.2), and man-made materials (8.3.4.2.4.5). The DOE agrees that a seismic loading task should be included. A more detailed description of the thermal and mechanical field tests and how they will be integrated with other field studies will be included in the next revision of this study plan.

NRC Question 3:

What potential impacts from non availability of data from other studies and ESF validation experiments have been considered? Would the data from this study be sufficient to validate the numerical codes?

DOE Response to NRC Question 3:

Verification and validation of models and codes is of great concern to DOE, and it is clear that the models to be used in this study plan cannot be verified and/or validated using data from this study alone. The NRC recommends that a minimum cut-off for the amount of data required for activities in this study plan be established and that provisions be added to the study plan which provide for the development of alternative approaches to validation and verification. This is an appropriate suggestion, and it will be considered at the time the next revision of the study plan is undertaken in FY 95.

NRC Question 4:

What method will be used to predict the long-term thermomechanical responses of field borehole damage and long-term radiation effects from laboratory scale rock samples and short-term radiation experiments?

DOE Response to NRC Question 4:

The NRC raises particular concerns regarding extrapolation of results from laboratory tests at elevated stress and temperature conditions and inclusion of scale and radiation effects. The DOE finds that prediction of long term behavior of a natural geologic system modified by an engineered facility must be based on modeling. It is the only tool capable of extending our knowledge from localized measurements over short periods of time to the performance of the entire repository for thousands of years. The approach taken by the DOE is that experiments and tests can be used to provide input on the time, temperature and scale dependence of parameters that are critical to the model behavior. Moreover, laboratory tests on small core samples can be used to validate some concepts of the models, and larger scale tests that can incorporate more inhomogeneities, such as fractures, can be used to confirm and validate more complete model calculations. Finally, in situ field tests can be used to confirm the model predictions of the performance of an entire repository.

The NRC recommends that this study plan be revised to include discussion of stress ratios and temperatures required in short-term tests to simulate the borehole damage expected in a repository. The DOE will address this concern in the next revision of this study plan by expanding and clarifying the discussion of conceptual models to be used in the long term simulations of geomechanical behavior, how some of the laboratory and field experiments will be used to provide input to these models and how other experiments and tests will be used to verify/validate the models.

The DOE agrees that the discussion of scale effects should include more information on the techniques that can be utilized to address this problem. Additional discussion will be added to the next revision of the study plan. This discussion will include information on empirical methods used in standard engineering practice, as well as other more quantitative techniques that can be used to address scale effects. These include statistical models for material behavior that employ scale independent concepts such as percolation theory and self-organized criticality.

Finally, the NRC recommends that additional discussion be added to the study plan to explain how short term tests to determine the effects of radiation on geomechanical behavior will be extrapolated to the long term behavior of the repository. The DOE finds that it is appropriate to revise the discussion in the study plan to clarify how the effect of radiation will be assessed and this will done in the next revision of the study plan. The strategy of the DOE for radiation effects follows the general strategy stated above: laboratory measurements will be made on irradiated and non-irradiated samples to measure the effect of radiation on key model parameters such as unconfined compressive strength and subcritical crack growth rate. These parameters will then be input into conceptual models implemented numerically using computer

codes. The numerical models will be used to assess the long term effects of radiation. Radiation is not expected to affect the mechanical properties. However, if the laboratory and/or modeling studies show some effect, then a more detailed study should be designed and implemented.

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