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MEMORANDUM FOR: Joseph J. Holonich, Chief
High-Level Waste and Uranium Recovery Projects Branch
Division of Waste Management, NMSS

FROM: Mike Bell, Chief
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Division of Waste Management, NMSS

SUBJECT: Review of DOE Study Plan 8.3.1.15.1.2 - "LABORATORY THERMAL
EXPANSION TESTING"

This memo transmits the review results of DOE Study Plan (SP) 8.3.1.15.1.2, Revision 1. The review was conducted in accordance with the procedures in the "Review Plan for NRC Staff Review of DOE Study Plan, Revision 2, March 10, 1993". Based on this review, we have four questions on this SP. The reasons for this conclusion are based on the findings for the five review criteria in Section 4.1 of the review plan, and the evaluations of the SP with respect to the objectives of the review given in Section 2.2 of the review plan. The findings for ten objectives are summarized below:

1. The level-of-detail of this SP is generally consistent with the NRC/DOE agreement of May 7-8, 1986.
2. The objectives of this SP are generally consistent with the objectives of the Laboratory Thermal Expansion Testing presented in the Site Characterization Plan (SCP). The objective of this SP is to provide laboratory data on thermal expansion required by repository design and performance assessment. This SP describes the rationale for obtaining thermal-expansion data, specific requirements for the data, and the plans for experiments to obtain coefficients of linear thermal expansion. The primary emphasis of this plan is to examine the variability of the thermal-expansion behavior as a function of rock type and spatial location. The SP also focuses on the examination of possible effects of fractures or lithophysal cavities on thermal expansion. The effects of presence or absence of thermal-expansion anisotropy in the welded, devitrified Topopah Spring Member of the Paintbrush Tuff will also be studied.
3. No field test is proposed in the current SP, nor are additional boreholes proposed. Therefore, no activities of this SP could affect repository performance and cause significant unmitigable impact on the waste isolation characteristics of the site.
4. The rock sampling activity of this SP is expected to have minimal impact on other site characterization activities or construction of the Exploratory Studies Facility (ESF).

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5. The SP is developed under OCRWM approved and NRC accepted Quality Assurance (QA) program. High-Level Waste and Uranium Recovery Project Branch (HLUR) staff upon reviewing this SP concluded that there are no potential QA-related issues.
6. No radioactive material will be used in in situ testing except for gamma-irradiated samples used in the laboratory thermal expansion tests to evaluate the radiation effects. To study the radiation effects on the thermal expansion characteristics of the rock, the use of radiation is inevitable.
7. It is likely that the SP enables DOE to obtain information for licensing. However, the staff notes that there is lack of integration among similar SPs just as it was observed in other SP reviews. For example, this SP states that some of the samples will be provided under SP 8.3.1.15.1.5 (Excavation Investigations), but there is no mention of that in the SP 8.3.1.15.1.5.
8. DOE has provided some information on SCA Comment 55 in the cover letter of this SP, however does not request closure of this open item. Staff has evaluated the information and considers SCA Comment 55 open. The evaluation of SCA Comment 55 is included in the enclosure of this Memo.
9. The staff has identified four questions during review of this SP. The detailed review results are also included in the enclosure.
10. No new items were identified for the OITS.

The enclosure presents the findings and questions generated by this review. The technical review was conducted by Dr. Shiann-Jang Chern, and Internal Quality Assurance (IQA) was performed by Dr. Mysore Nataraja. If you have any questions regarding this review, please contact Dr. Shiann-Jang Chern at 415-6613.

(ORIGINAL SIGNED BY:

M. Nataraja)

for: Mike Bell, Chief
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Enclosure: As stated

cc: M. Lee, HLUR w/encl.

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Enclosure

REVIEW OF DOE STUDY PLAN 8.3.1.15.1.2, REVISION 1 - "LABORATORY THERMAL EXPANSION TESTING"

The review of DOE Study Plan (SP) 8.3.1.15.1.2 is based on the "Review Plan for NRC Staff Review of DOE Study Plan", Revision 2, dated March 4, 1993. SP reviews are intended to accomplish the following: (1) confirm that the SPs contain the material specified in the Agreement on content of SPs, (2) identify objections with respect to the studies, (3) evaluate whether any open items that DOE has proposed for closure on the basis of the SPs, and (4) evaluate the adequacy of the SPs to provide the information for licensing.

The primary purpose of this SP is to provide all of the data on thermal expansion required by repository design and performance assessment that can be obtained in a laboratory setting. The revision 1 of the SP describes: (1) the rationale for obtaining laboratory thermal-expansion data, (2) the determination of specific requirements for the data, and (3) the specific plans for experiments to obtain data on the coefficient of linear thermal expansion. The laboratory test samples will be taken from (1) existing core holes, (2) main accesses of the ESF, (3) main drifts to be excavated within Unit TSw2 of the ESF, and (4) new core holes proposed as part of surface-based exploration program.

A scoping study will be conducted to establish a baseline for the laboratory thermal expansion test conditions. The important effects of parameters such as, confining pressure, sample size, and saturation level of the samples, on thermal expansion will be evaluated separately before conducting thermal expansion measurement. The preliminary estimate of the necessary number of samples for the thermal expansion testing is made using a statistical method. Rock sample anisotropy, effects of confining pressure on the fractures, and radiation effect on the thermal expansion will be examined during the thermal expansion measurement. Experiments, the quality assurance (QA) requirements, and technical procedures are also discussed in this SP. Data obtained in this SP activities will be used to estimate of coefficients of thermal expansion for the rock mass. Then, the data for the rock mass coefficient will be compared to values obtained during in situ thermal expansion experiments. Finally the rock mass thermal expansion behavior will be extrapolated.

The review findings are presented below corresponding to the five review criteria in the Review Plan.

1. Evaluation of Study Plan Relative to the Agreement and to the Responsible DOE Contractor's QA Program

The NRC staff has evaluated this study plan to determine if the content of the SP is reasonably consistent, as appropriate for the activities, tests, and analyses described, with the Agreement. The staff also considered any open items concerning the QA program under which the SP was developed. The conclusions of the review are:

1. This SP is generally consistent with the NRC/DOE agreement on Level-of-Detail Agreement.

2. There are no QA related open items in this SP.

2. Identification of Objections

The review did not identify any objections to the study plan. The conclusions of the review are:

1. The objectives of this SP are consistent with the objectives of the Laboratory Thermal Expansion Testing presented in the Site Characterization Plan (SCP). The primary purpose of this SP is to characterize the thermal expansion properties and to provide all of the data on thermal expansion required by repository design and performance assessment that can be obtained in a laboratory setting. This SP describes the rationale for obtaining thermal expansion data, the specific requirements for the data, and the specific plans for experiments to obtain the data on linear thermal expansion. The primary emphasis of this SP is to examine the variability of the thermal-expansion coefficient as a function of rock type and spatial location. Other objectives include the examination of possible effects of fractures or lithophysal cavities on thermal expansion. The effects of presence or absence of thermal expansion anisotropy in the welded, devitrified Topopah Spring Member of the Paintbrush Tuff will also be studied.
2. No field investigations are planned in the current version of the SP, nor are additional borings proposed for sampling. Therefore, no activities of this SP could affect repository performance and cause significant unmitigable impact on the waste isolation characteristics of the site.
3. The rock sampling activity of this SP is expected to have minimal impact on other site characterization activities or construction of the Exploratory Studies Facility (ESF).
4. The SP is developed under OCRWM approved and NRC accepted Quality Assurance (QA) program. HLUR staff, upon reviewing this SP, concluded that there are no potential QA-related issues.
5. No radioactive materials will be used in in situ testing except for gamma-irradiated samples used in the laboratory thermal expansion testing to evaluate the radiation effects. Because the objective is to study the effects of radiation in the thermal expansion characteristics of the rock, the use of radiation is an inevitable part of testing.

3. Resolution of NRC Open Items

The staff reviewed to determine whether DOE has proposed, in its letter transmitting the SP, to resolve any NRC open items. The response to the analysis of SCA Comment 55 was discussed in the DOE transmitting letter. But DOE has not formally requested resolution of this comment. The SCA Comment 55 is related to the SCP Section 8.3.1.15.1 Investigation: Studies to provide the Required Information for Spatial Distribution of Thermal and

Mechanical Properties.

SCA Open Comment 55

The discussion and/or use of statistics in this chapter is not clear. A statistical approach has been suggested to determine numbers of tests required to determine various rock properties, but the approach suggested is confusing and apparently overlooks several considerations that should be factored into such an approach. Also, needed confidences of "low," "medium," or "high" have been assigned without explaining the basis for such assignment. (NRC, 1989)

DOE's Response

- In response to SCA Comment 55 on SCP Section 8.3.1.15.1, DOE explained the rationale and basic assumptions of statistical analysis to determine the numbers of tests.
- The SP makes the following assumptions:
 - a. The thermal expansion properties are evenly distributed throughout the mass of each thermal/mechanical unit. This assumption will not apply to the entire rock mass.
 - b. The measured values are not a function of testing sample size or direction. If scoping studies find that testing sample size or direction will have a significant effect on the thermal expansion behavior, the sampling and test program will be modified.
 - c. The populations are normally distributed. The existing thermal expansion data show the populations are normally distributed.
 - d. The sampling is not biased due to jointing, hole direction, etc. Each thermal/mechanical unit will be divided into n potential sampling intervals, where n is the number of samples specified in Table 2.2-2 of the SP. If sampling locations are close to the center of each interval, the bias of sampling can be avoided. Adjustments of sampling program may be necessary.
 - e. The determination of the necessary number of samples is based on a Gaussian tolerance level. Two-sided statistical tolerance limits are used in these estimates.
- The SP also states that "data requirements and associated qualitative confidence levels was based on the expert judgement of repository personnel with little or no support in the form of sensitivity analysis. If additional analyses indicate a change in sensitivity to thermal expansion behavior from that assumed in the SCP, the numbers of samples required for experiments will be adjusted appropriately."

Evaluation of DOE Response

- In response to SCA comment 55, DOE doesn't explain how the n sampling intervals would be divided in a thermal/mechanical unit. It is unclear whether n sampling intervals will have equal thickness or not. If n equal intervals were selected in a nonuniform thermal/mechanical unit, an artificial bias may be introduced. There is no guarantee that the statistical bias will be eliminated even if the sampling location is close to the center of each interval. In the field, jointing may not be uniformly distributed in a thermal/mechanical unit. Therefore, best representative rock samples picked in a thermal/mechanical unit may not necessarily be in the central part of each interval. On the other hand, if unequal intervals will be selected, what are the criteria for selection of intervals? DOE should pay more attention on the samples which have fractures and joints and take into account their directions.
- NRC staff agrees that the sampling program needs to be modified, if core samples show that the statistical assumptions are invalid. Staff suggests that DOE explain how the n intervals are divided. Staff believes that SCA Comment 55 will not be resolved until the statistical assumptions are verified. Therefore, the NRC staff considers this comment open.

4. Evaluation of Study Plan Relative to Obtaining Data Needed for Licensing

NRC staff evaluated the activities, tests, and analyses of this SP and has the following questions:

Question 1.

Will this SP investigate the effects of anisotropy and natural fractures on the thermal expansion characteristics of the samples collected from the ESF Main Access, ESF Main Drifts, and additional sampling locations and the thermal/mechanical units other than TSw2 ?

Basis

Scoping studies will be conducted to examine the effects of confining pressure, sample size, and the saturation level on the thermal expansion tests behavior and establish test baseline conditions.

For each new core hole, the presence of anisotropy, natural fractures, and their effects on the coefficient of thermal expansion will be examined for the unit TSw2. However, the SP does not address whether the anisotropy and natural fractures will be examined on the ESF Main Access samples (section 2.2.2.2), ESF Main Drifts samples (section 2.2.2.3), and additional location samples (2.2.2.4). It is unclear whether the anisotropy and natural fractures will be examined on the thermal/mechanical units other than TSw2.

Recommendation

It is recommended that DOE should include a discussion in the SP on whether the anisotropy and natural fractures will be examined while testing samples from the ESF Main Access, additional locations, and the units other than TSw2 in new core holes.

Question 2.

Does the program described in this SP (Table 2.2-4) provide enough flexibility to accommodate the DOE's high thermal loading option for the repository design?

Basis

DOE has not decided to use the hot or cold thermal loading option on the repository design (NWTRB, 1992). The multi-purpose canisters (MPC) design concept suggests that DOE may choose high thermal loading option. If DOE decides to choose a high thermal loading for the repository design, the maximum temperature on the surrounding rock may be higher than the current 300°C design level. Therefore, the proposed 300°C thermal range of laboratory experiments of the current SP may need to be revised.

Recommendation

It is recommended that the DOE's alternatives on thermal loading option be considered in the SP.

Question 3.

What is the rationale for applying the confining pressure normal to the fractures?

Basis

The SP states that all tests on fractured samples will include a small stress ($< \text{ or } = 7 \text{ MPa}$) normal to the fracture in order to simulate in situ conditions. The fractures in the Yucca Mountain are nearly in vertical direction. The overburden stress is nearly parallel to the fractures. DOE doesn't provide the rationale why the confining pressure is normal to the fractures. DOE doesn't explain why the overburden stress 7 MPa is a small stress. DOE doesn't explain why the higher stress is not considered.

Recommendation

It is recommended that DOE provides appropriate rationales for the magnitude and direction of the confining stresses considered.

Question 4.

What is the rationale for heating up and cooling down the TSw2 first, then using the same samples for examining the radiation effects on thermal expansion?

Basis

The SP states that twenty TSw2 samples will be tested for thermal expansion. After thermal expansion test, ten TSw2 samples will be irradiated. Then, the ten irradiated and ten nonirradiated samples will be retested to examine the radiation effect on the thermal expansion.

The thermal effects on the geochemical properties of fracture filling may be irreversible. After heating up the rock samples during thermal expansion measurement, the fracture filling such as clay may be dehydrated and more fractures may be induced during the heating and cooling process. Some uncertainty may be introduced after first thermal cycle. It may not be meaningful to compare the thermal expansion results under first and subsequent thermal cycles because the initial conditions such as degree of saturation, number of fractures, and fracture filling for the later thermal cycles could be changed. Therefore, the radiation effects on thermal expansion may be very difficult to quantify.

Recommendation

DOE needs to address the uncertainty of multi-cycle thermal effects on the thermal expansion test. Some test methods may be used to eliminate the uncertainty for the thermal expansion tests. One method may be to vertically split a larger diameter TSw2 rock samples into two sets of smaller diameter samples for examining the radiation effects on thermal expansion. It is also feasible to re-core a larger diameter sample into two sets of smaller diameter samples. One set of smaller diameter sample could be subjected to gamma radiation while the other set could be the base case. The two sets of samples should be tested under the same test control conditions to examine the radiation effects on thermal expansion.

5. Evaluation of Progress Toward Resolution of NRC Open Items

The activities proposed in this SP need to verify the statistical assumptions and measure the thermal expansion. The evaluation of statistical assumptions (SCA Comment 55) is discussed in item 3 above. DOE needs to explain how the n sampling intervals would be selected. Until the statistical assumptions are verified, NRC staff considers SCA Comment 55 open.

REFERENCES:

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

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