February 14, 2003

Joseph D. Ziegler, Acting Assistant Manager
Office of Licensing and Regulatory Compliance
U.S. Department of Energy
Office of Repository Development
P.O. Box 364629
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SUBJECT: STAFF REVIEW OF INFORMATION ADDRESSING RADIONUCLIDE TRANSPORT (RT) AGREEMENT 3.06 AND STRUCTURAL DEFORMATION AND SEISMICITY (SDS) AGREEMENT 3.02; STATUS PARTLY RECEIVED

Dear Mr. Ziegler:

In your letter dated June 27, 2002, the U.S. Department of Energy (DOE) responded to the U.S. Nuclear Regulatory Commission (NRC) additional information request and enclosed a report, "Updated Pre-Test Prediction of Tracer Transport for Alcove 8 - Niche 3 Cross-Over Fault Test (Phase I)." NRC staff has reviewed this information, with respect to RT Agreement 3.06 and SDS Agreement 3.02. The results of the staff's review are enclosed.

In response to the additional information needs, the DOE letter states (i) that Phase II pre-test predictions will be available after the fiscal year 2002, (ii) that the pre-test predictions discussed in the previous report and its attachment II are for the Small Plot Test, and (iii) that the main objectives of the Line Release (Fault) Test are indicated in Liu (2002). The response concerning the Phase II pre-test predictions requiring this additional information need remains unfulfilled. The responses to (ii) and (iii) are considered adequate.

DOE also suggests that since the two agreement items are identical, SDS.3.02 be closed and the remaining information be tracked under RT.3.06. The staff considers that the hydrologic tests at Alcove 8–Niche 3 provide direct measurements of movement of water through faults and fractures at a scale that can and should be tied to detailed structural geologic observations and measurements. Consequently, because it is important to retain the perspective of fracture informing tests and pre-test predictions, SDS.3.02 should remain an open commitment until the additional information need has been fulfilled.

Although Agreements RT 3.06 and SDS 3.02 are focused on the documentation of the pre-test predictions, the staff is ultimately interested in the results and analysis of the Alcove 8-Niche 3 experiments. These experiments have the potential to provide significant information to support understanding of the movement of water through faults and fractures and fracture-matrix interaction mechanisms (e.g., matrix diffusion) in the unsaturated zone. Therefore, documentation of the analysis of the results of these experiments, including the discussion of the comparison with the pre-test predictions, will be used in evaluating DOE's understanding of flow and transport processes potentially important to performance. We look forward to DOE's documentation of the results once these experiments are completed and analyzed. In our previous letter on the Alcove 8-Niche 3 experiments (dated February 6, 2002), we identified a

variety of topics associated with understanding the experimental results relative to the pre-test predictions such as appropriateness of continuum approach, relationship of flow system to the area of fracture-matrix interaction, mass balance and recovery of water and tracer, and potential for interference between experiments. Discussion of these topics is appropriate after the experiments are completed and DOE has analyzed the results. The NRC staff looks forward to reviewing the documentation of the results and analysis of these experiments.

Pending receipt of the additional information previously requested concerning the Phase II pre-test predictions, agreements RT.3.06 and SDS.3.02 are considered partly received. If there are any questions regarding this letter, please contact William Dam at 301-415-6710 or by e-mail at wld@nrc.gov.

Sincerely,

/RA/

Janet R. Schlueter, Chief
High-Level Waste Branch
Division of Waste Management
Office of Nuclear Material Safety
and Safeguards

Attachment: NRC Review of DOE Letter Pertaining to RT.3.06 and SDS.3.02.

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Letter to J. Ziegler from J. Schlueter dated February 14, 2003

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NRC Review of DOE Documents Pertaining to
Key Technical Issue Agreements RT 3.06 and SDS 3.02

The U.S. Nuclear Regulatory Commission (NRC) goal of issue resolution during this interim pre-licensing period is to assure that the U.S. Department of Energy (DOE) has assembled enough information on a given issue for NRC to accept a licensing application for review. Resolution by NRC staff during pre-licensing does not prevent anyone from raising any issue for NRC consideration during the licensing proceedings. Just as important, resolution by NRC staff during pre-licensing does not prejudge what the NRC staff evaluation of that issue will be after its licensing review. Issues are resolved by NRC staff during pre-licensing when the staff has no further questions or comments about how DOE is addressing an issue. Pertinent new information could raise new questions or comments on a previously resolved issue.

This enclosure addresses two agreements, RT 3.06 and SDS 3.02, which were reached between NRC and DOE during two technical exchange and management meetings.[1,2]

Wording of the Agreements

RT 3.06 and SDS 3.02 both state: "The NRC needs DOE to document the pre-test predictions for the Alcove 8–Niche 3 work. DOE responded that pre-test predictions for Alcove 8-Niche 3 work will be provided to NRC via letter report (Brocoum to Greeves) by mid-January 2001."

NRC Review

Background

The seepage and transport testing planned and conducted at Alcove 8-Niche 3 provides one of the few opportunities for DOE to collect in situ data to confirm unsaturated zone transport parameters and validate unsaturated zone conceptual models for flow and transport. As such, the Alcove 8-Niche 3 tests are the subject of several agreement items covering a number of key technical issues, including Radionuclide Transport, Unsaturated and Saturated Flow Under Isothermal Conditions, Structural Deformation and Seismicity, and Total System Performance Assessment and Integration. Specifically, agreement items RT 3.06 and SDS 3.02 asked DOE to document pre-test predictions for the flow and transport testing at Alcove 8-Niche 3.

Agreement RT 3.06 stems from staff concerns described in the RT Issue Resolution Status Report Rev 2 (2000) that estimation of transport through fractured rock is relatively untested. In comparison, estimation of transport in porous rock is supported by years of chemical engineering experience in chromatographic techniques. When credit is to be taken for radionuclide attenuation in fractured rock, the staff proposed as an acceptance criterion, that DOE should show a capability to predict breakthrough curves of reactive, nonreactive, and colloidal tracers in field tests. This acceptance criterion methodology is compatible with current and past approaches used by DOE in which results of simple laboratory tests are used to predict the results of more complex tests (e.g., batch sorption tests are used to predict column test breakthrough curves.) The intent of the acceptance criterion is that the capability to predict

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[1]Reamer, C.W. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Radionuclide Transport (December 5–7, 2000)." Letter (December 12, 2000) to S. Brocoum, DOE.

[2]Schlueter, J.R. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Structural Deformation and Seismicity (October 11-12, 2000)." Letter (October 27, 2000) to S. Brocoum, DOE.

small scale field tests could build confidence in DOE's understanding of flow and transport processes potentially important to performance.

Agreement SDS 3.02 stems from staff concerns described in the SDS Technical Exchange meeting summary concerning (1) role of mineralized fractures in the unsaturated zone, (2) DOE's technical basis for fracture-related parameters used in process models, and (3) tests to calibrate unsaturated zone models of seepage. DOE indicated that each of these concerns would be addressed by Alcove 8-Niche 3 tests (footnote 3). The Agreement SDS 3.02 intends for DOE to fracture-inform the pre-test Alcove 8-Niche 3 predictions in a similar manner to DOE fracture-informing the test-results (see SDS 3.01). Fracture-informing the test predictions and test results ensures that fracture-related parameters initially used to set-up tests and possibly, to interpret test results, are ultimately technically-based on actual observations and measurements of fracture properties.

In response to agreement items RT.3.06 and SDS.3.02, DOE provided by letter[3] in March, 2001, the Pre-Test Predictions for Alcove 8-Niche 3 Cross-Over Test (Liu, 2001). NRC staff reviewed the Liu (2001) report, provided twelve comments, three of which are also listed as additional information needs (AIN) in a subsequent letter.[4] The additional information needed by NRC included (i) pre-test predictions for the Phase II tests (flow and transport), for the Line Release (Fault) test, and the Large Plot Test, (ii) clarification of whether the tracer transport tests for the small plot tests discussed in the Pre-Test Prediction Report, and the pre-test predictions in Attachment II of the report (Liu, 2001), are the pre-test predictions for the Small Plot Test or the Line Release (Fault) Test or both, and (iii) clarification on the specific test objectives of the Line Release (Fault) Test. The remaining general comments related to the test plans and pre-test predictions. In general, the nine comments emphasized the importance of the Alcove 8-Niche 3 tests and the relationship of the tests to several existing agreement items. NRC requested that the general comments be considered by DOE with regard to conducting other tests and associated pre-test predictions. NRC also requested that DOE consider ways of fracture-informing its response to RT 3.06 and SDS 3.02.[5] At the RT Technical Exchange, DOE presented a study suggesting that of the various strata in the unsaturated zone, the fractured Topopah Spring provided the most isolation capability. Consequently, testing in this portion of the unsaturated zone is risk significant.

Summary of the Information Provided by DOE

DOE transmitted a letter[6] in June 2002 that responds directly to the three additional information needs identified in the NRC response letter of February 6, 2002. The letter also includes an enclosure report entitled "Updated Pre-Test Predictions of Tracer Transport for

[3]Brocoum, S. "Response to Radionuclide Transport Key Technical Issue Technical Exchange: Subissue 3, Agreement 6; and Structural Deformation and Seismicity Key Technical Issue Technical Exchange: Subissue 3, Agreement 2." Letter (March 12, 2001) to C. Reamer.

[4]Reamer, C.W. "Radionuclide Transport Key Technical Agreements." Letter (February 6, 2002) to S. Brocoum, DOE.

[5]Schlueter, J., "Structural Deformation and Seismicity Key Technical Issue Agreement Letter (May 21, 2002) to J. D. Ziegler.

[6]Ziegler, J. "Transmittal of information addressing Key Technical Issue (KTI) Agreement Items Radionuclide Transport (RT) 3.06 and Structural Deformation and Seismicity (SDS) 3.02." Letter (June 27, 2002) to J. Schlueter.

Alcove 8-Niche 3 Cross-Over Fault (Phase I)" (Liu, 2002). In response to the additional information needs, the DOE letter states (i) that Phase II pre-test predictions will be available after the fiscal year 2002, (ii) that the pre-test predictions discussed in the previous report and attachment II are for the Small Plot Test, and (iii) that the main objectives of the Line Release (Fault) Test are indicated in Liu (2002). In addition, the DOE June 27, 2002 letter also notes that the Cross-Over Fault Test is also called the Linear Release Test. DOE also suggests that since the two agreement items are identical SDS.3.02 be closed and the remaining information be tracked under RT.3.06.

The report (Liu, 2002) provides updated pre-test predictions for the Small Plot Test including an alternative conceptual model of fault-fracture connectivity and provides preliminary results of observations of the arrival of seepage and tracer at Niche 3. The report indicates that updated pre-test predictions were warranted based on observations of wetting in Niche 3 that implied considerable communication between the fault and surrounding fracture networks and because the initial conditions assumed in the previous pre-test predictions had been modified by design or were observed to be different in the actual testing. The report provides model calibration results using observed infiltration and seepage data, and provides pre-test predictions for transport of tracers using two conceptual models, one with fault-fracture communication and one considering the fault to be isolated from fracture networks. The report notes that preliminary results from the tests indicate that recoverability (total volume of water collected at Niche 3 divided by the total volume applied at the infiltration plot in Alcove 8) is less than 10% although the seepage rate tends to stabilize after 60 days. Preliminary results of Br^- concentration measurements in seeping water show initially low concentrations (~3 ppm) that increased to the concentration value of Br^- applied at the infiltration plot (30 ppm) about 30 days after seepage occurred.

Staff Comments

Several concerns expressed by the NRC staff in the February letter were not addressed by the June 27th letter and are reiterated and updated in today's review of DOE's letter report. Based on the review of the pre-test prediction reports (Liu, 2001; 2002), it is apparent that several unsaturated flow and transport model concerns must be closely tracked within several other applicable Key Technical Issue agreement items (e.g., RT.3.05, SDS.3.01, TSPAI.3.25, USFIC.4.01, and USFIC.6.03). These concerns can be addressed within DOE documents pertaining to those applicable Key Technical Issue agreements.

To date, DOE prognoses for Alcove 8-Niche 3 have not been fully realized. For the Line Release (Fault) Test [Small Plot tracer test as discussed in Liu (2002)], DOE provided two model predictions to bound the possible breakthrough curves to be expected from the ongoing tests (Liu, 2002). Recently presented preliminary results indicate significant fault-fracture communication and breakthrough of tracers that is delayed and significantly diminished in recovery relative to the predictions of Liu (2002).[7] The preliminary results present evidence of matrix diffusion processes, but validation of model parameters may be difficult given the remaining uncertainties in flow paths and matrix imbibition. Observations made by NRC staff during visits to the Exploratory Studies Facility and the Alcove 8-Niche 3 test area indicate the vertical continuity of the fault and lateral communication extent of fractures assumed in the pre-test prediction model may not be sufficient to encompass actual test conditions and results.

[7]M.T. Peters. "Science and Engineering Update." Presentation to the Nuclear Waste Technical Review Board, September 10, 2002. BSC Presentations_NWTRB_YMPeters_091002.ppt.

This observation supports the need to fracture-inform the test (SDS.3.01) as well as the pre-test prediction (SDS.3.02).

The staff considers that the hydrologic tests at Alcove 8-Niche 3 provide direct measurements of movement of water through faults and fractures at a scale that can and should be tied to detailed structural geologic observations and measurements. Consequently, because it is important to retain the perspective of fracture informing tests and pre-test predictions, SDS.3.02 should remain open until the additional information need has been fulfilled.

Previous Additional Information Need 1

DOE stated that planning for Phase II pre-test predictions is currently being finalized, and that these predictions will be available after fiscal year 2002. This additional information need (AIN) remains unfulfilled. It is important that pre-test predictions be completed and reported prior to initiation of the test. Given the uncertainty regarding timing of Phase II testing, the timing of fulfillment of this information need should be provided both in terms of date of delivery and relative date of delivery with respect to conducting Phase II testing. DOE should address this concern in response to Agreements RT.3.06/SDS.3.02.

Comment 1
DOE stated that tracer transport results for the small-plot tests discussed in the Pre-Test Prediction report, and the pre-test predictions in Attachment II to the Pre-Test Prediction Report, are the pre-test predictions for the small-plot test. This information fulfills the second AIN in the NRC letter[4] describing the staff review of the initial Pre-Test Predictions report by clarifying the names of the various tests. The NRC staff's understanding was that the Small Plot Test was aborted in favor of the Line Release (Fault) Test because of the unexpectedly small infiltration rate and because injection with and without tracers (Phase I) at ponded influx rates was more successful for the Line Release (Fault) Test.

Because the location and dimensions for the Line Release Test [as named in Liu (2001)], which appears to be the same as the modified Small Plot Test (Liu, 2002), were not provided in the enclosed or the previous pre-test prediction and test plan reports (Liu, 2001; 2002), it is still difficult to unambiguously identify the tests and to link the tests' initial conditions and assumptions with pre-test modeling predictions.

DOE should provide a complete description of the actual tests by including physical dimensions, experimental set-up, and initial conditions, such that NRC staff could identify the tests to which the pre-test predictions apply. A comparison of the pre-test predictions to the results can be used as a measure of DOE's understanding of flow and transport processes potentially important to performance. DOE should address this concern in response to Agreements RT.3.05 and SDS.3.01.

Comment 2
The pre-test predictions used the active fracture model, a continuum model, to simulate wetting of the volume of rock between Alcove 8 and Niche 3. The use of a continuum model is inappropriate when the spacing of flowing fractures exceeds the grid size. Liu, Doughty, and Bodvarsson (1998, p. 2642) correctly acknowledge this type of limitation in the statement, "continuum approaches are not applicable because very few fractures are active within a grid block and fracture flow can not be captured by continuum models." The two-dimensional spatial distribution of matrix saturation increase at times of 1 year and 10 years after the test. The grid size for this simulation is one meter or less. However, Table 1 lists fracture spacing in TSw33 to be 1.23 m, which is greater than the grid size. Furthermore, using an active fracture model, the spacing of fractures in which

water flows is expected to increase under less than fully saturated conditions. In predicting flow and transport in Alcove 8-Niche 3 tests, DOE needs to justify its use of a continuum model when the spacing of flowing fractures exceeds the grid size. DOE should address this concern in response to Agreements RT.3.05, SDS.3.01, and USFIC.6.03.

Comment 3
Another continued concern is that it is not clear to NRC staff how the pre-test predictions can be meaningfully compared to the test results of the Alcove 8-Niche 3 Crossover Test without a mass balance of water. Recoverability is defined in the Pre-Test Prediction Report as the total volume of water collected at Niche 3 divided by the total volume of water applied from the infiltration plot. NRC staff previously expressed concern that without accurate consideration of the amount of water lost from evaporation, calculated recoverability will provide unreliable information. Observed recoverability (less than 10%) at Niche 3 is even less than the low predicted values provided in Liu (2001). The value of the pre-test predictions would be greatly diminished if the Alcove 8-Niche 3 tests lack a mass balance of water. For example, without an accurate water budget, the unsaturated zone constitutive relations (e.g., van Genuchten parameter values) cannot be estimated correctly. Similarly, breakthrough behavior of tracers will likely be dramatically affected by multiple flow paths in the fault-fracture connected system, and interpretation of breakthrough curves will be difficult without a reasonable accounting of tracer mass. DOE should address this concern in response to Agreements RT.3.05, SDS.3.01, and USFIC.6.03.

Comment 4
The basis for using the rock property values from Table 1 (p. 10) in the "Updated Pre-Test Predictions of Tracer Transport for Alcove 8-Niche 3 Cross-Over Fault (Phase I)" is not clear. More recent and representative rock property data are available to run predictive simulations (D. Coleman, Appendix 7 on fractures, 12/19/02). DOE needs to clarify the basis and give the rationale for using the values listed in Table 1. DOE should address this concern in response to Agreements RT.3.05, SDS.3.01, and USFIC.6.03.

Comment 5
An NRC staff concern pertains to the test objective of evaluating the fracture-matrix interface area as described in the Pre-Test Prediction Report. If saturated conditions have existed prior to tracer injection, the wetted fracture-matrix interface area will be large during and immediately after saturated conditions. Fracture sheet flow may continue until the fractures begin to dry out. If unsaturated, relatively dry conditions exist prior to tracer injection, fracture sheet flow would be less likely to occur. More likely would be finger-type preferential flow paths and, therefore, a smaller wetted fracture-matrix interface area. Such preferential flow in the fractures would lead to more rapid movement of water and tracer. By isolating flow to a small fraction of the volume of the medium, the rate of vertical movement can be significantly increased, leading to less sorption and less matrix diffusion. Clarification is needed on how the effects from previously saturated fractures will be considered when evaluating the fracture-matrix interface area, or give the rationale for why these effects need not be considered. DOE should address this concern in response to Agreements RT.3.05, SDS.3.01, and USFIC.6.03.

Comment 6
An additional staff concern pertains to the Pre-Test Prediction Report assumption that fracture-matrix interaction mechanisms are the same for the water flow from the fracture continuum to the

matrix continuum as they are for water flow from the matrix continuum to the fracture continuum. This issue is roughly analogous to hysteresis of unsaturated water flow in porous media. The fracture-matrix interaction mechanisms can be very different depending on whether the saturation of the flow system is increasing or decreasing. Liu, Doughty, and Bodvarsson (1998, p. 2638) stated that this issue needed further study. The rationale for assuming that fracture-matrix interaction mechanisms are the same for, and independent of, a flow system which is increasing or decreasing in saturation is needed. DOE should address this concern in response to Agreements RT.3.05 and USFIC.6.03.

Comment 7
The Pre-Test Prediction Report states that the fracture relative permeability and the fracture-matrix interface area are functions of flux for Phase II unsaturated flow and transport test components. The NRC staff concern is how DOE will determine if the fracture-matrix saturation system is not in a state of disequilibrium due to the rapidity of the sequence of tests. Flow and transport between the fractures and the matrix may still be ongoing from Phase I and interfere with the results of Phase II. DOE needs to address the staff concern about the possibility of sequential Phase II test interferences. DOE should address this concern in response to Agreements RT.3.05 and USFIC.6.03.

Comment 8
DOE should describe all features, events, and processes observed in Alcove 8-Niche 3 tests. The unexplained unsteady early infiltration rate is one example. NRC staff is aware of other examples which should be documented, e.g., a hole was drilled some distance from the fault when suddenly one section of the ponded water in the fault trench drained. Could DOE explain this event using the active fracture model? By documenting all FEPs observed in Alcove 8-Niche 3 tests, the staff can better evaluate the appropriateness of the models describing flow and transport. DOE should address this concern in response to Agreements RT.3.05/SDS.3.01 and USFIC.6.03.

Additional Information Needed: None

Status of Agreements: Pending receipt of the previous additional information need #1, agreements RT.3.06 and SDS.3.02 are considered partly received.

References

Liu, H.H. “Pre-Test Predictions for Alcove 8–Niche 3 Cross-Over Test.” Bechtel SAIC Company, LLC report provided by letter (March 12, 2001) from S. Brocoum to C. Reamer. February, 2001.

Liu, H.H. “Updated Pre-Test Prediction of Tracer Transport for Alcove 8–Niche 3 Cross-Over Fault Test (Phase I).” Bechtel SAIC Company, LLC report provided by letter (June 27, 2002) from J. Zielgler to J. Schlueter. June, 2002.

Liu, H. H., C. Doughty, and G. S. Bodvarsson, An active fracture model for flow and transport in fractured rocks, Water Resources Research, vol. 34, no. 10, pages 2633-2646, October 1998.