Summary Highlights of NRC/DOE Technical Exchange and Management Meeting on Thermal Effects on Flow

January 8-9, 2001
Pleasanton, California

Introduction and Objectives

This Technical Exchange and Management Meeting on Thermal Effects on Flow (TEF) is one in a series of meetings related to the U.S. Nuclear Regulatory Commission (NRC) key technical issue (KTI) and sufficiency review and the U.S. Department of Energy (DOE) site recommendation decision. Consistent with NRC regulations on prelicensing consultations and a 1992 agreement with the DOE, staff-level resolution can be achieved during prelicensing consultation. The purpose of issue resolution is to assure that sufficient information is available on an issue to enable the NRC to docket a proposed license application. Resolution at the staff level does not preclude an issue being raised and considered during the licensing proceedings, nor does it prejudge what the NRC staff evaluation of that issue will be after its licensing review. Issue resolution at the staff level, during prelicensing, is achieved when the staff has no further questions or comments at a point in time regarding how the DOE is addressing an issue. The discussions recorded here reflect NRC's current understanding of aspects of thermal effects on flow most important to repository performance. This understanding is based on all information available to date which includes limited, focused, risk-informed reviews of selected portions of recently provided DOE documents (e.g., Analysis and Model Reports (AMRs) and Process Model Reports (PMRs)). Pertinent additional information (e.g., changes in design parameters) could raise new questions or comments regarding a previously resolved issue.

Issues are Aclosed@ if the DOE approach and available information acceptably address staff questions such that no information beyond what is currently available will likely be required for regulatory decision making at the time of any initial license application. Issues are Aclosed-pending@ if the NRC staff has confidence that the DOE proposed approach, together with the DOE agreement to provide the NRC with additional information (through specified testing, analysis, etc.) acceptably addresses the NRC's questions such that no information beyond that provided, or agreed to, will likely be required at time of initial license application. Issues are Aopen@ if the NRC has identified questions regarding the DOE approach or information, and the DOE has not yet acceptably addressed the questions or agreed to provide the necessary additional information in a potential license application.

The objective of this meeting is to discuss and review the progress on resolving the TEF KTI (see Attachment 1 for the description of Subissues #1 and 2). The quality assurance (QA) aspect of this KTI was determined to be outside the scope of the meeting and is being tracked in NRC=s ongoing review of the DOE=s QA program.

Summary of Meeting

At the close of the Technical Exchange and Management Meeting, the NRC staff stated that Subissues 1 and 2 were "closed-pending." Specific NRC/DOE agreements made at the meeting are provided as Attachment 1. The agenda and the attendance list are provided as

Attachments 2 and 3, respectively. Copies of the presenters= slides are provided as Attachment 4. Highlights from the Technical Exchange and Management Meeting are listed below.

Highlights

1) Opening Comments

The DOE stated that the intent of the meeting is to reach agreement on the current status and path forward for each of the TEF subissues (see "Thermal Effects on Flow" presentation given by Deborah Barr). In the TEF Issue Resolution Status Report (IRSR), Revision 3, the NRC stated that TEF Subissues #1 and 2 are "open." During this meeting, the DOE stated that its presentation would focus on the open items identified by the NRC in the IRSR and subsequent discussions. The DOE stated that it felt that the details provided during the current meeting would be the basis for NRC to list Subissues 1 and 2 as "closed-pending."

The DOE stated that for Subissue #2, Open Items 3, 4, and 9 would not be discussed and that documents addressing these open items would be submitted to the NRC. The NRC has identified the documents needed to resolve the open items, including the relevant concerns, in the agreements pertaining to Subissue #2.

2) Uncertainties in Total System Performance Assessment for the Site Recommendation

The DOE provided an overview of ongoing activities to identify the treatment of uncertainties in Total System Performance Assessment (TSPA) for the Site Recommendation (see "Uncertainties in Total System Performance Assessment for the Site Recommendation" presentation given by Kevin Coppersmith). The DOE discussed three ongoing activities to evaluate uncertainties: uncertainty review, conservatism assessment, and unquantified uncertainties.

Regarding the uncertainty review, the DOE stated that it would perform a bottom-up review of uncertainty treatment in process models and abstractions. The DOE stated that guidance to PMR and AMR authors was as follows: (1) if there is sufficient data, it would use a probability distribution function, and (2) if there is large uncertainty or complexity, it would provide a conservative estimate that is technically defensible. The DOE stated that the TSPA-SR is a mix of distributions and conservative estimates. The DOE asserted that, because these are conservative inputs, the TSPA-SR results are conservative, but the magnitude of the conservatism has not been assessed. The NRC replied that conservative inputs do not necessarily translate to conservative outputs in nonlinear coupled systems. The DOE agreed and stated that the intent of the ongoing uncertainties activities is to evaluate the degree of nonlinearity between conservatism in inputs and conservatism in dose estimates.

Regarding the conservatism assessment, the DOE stated the purpose was to complete a qualitative evaluation of the representativeness/conservatism of features, events, and processes (FEPs) in process models. The DOE stated that the conservatism assessment was a starting point for the unquantified uncertainties activity. The DOE further stated that the conservatism review includes all conservatisms in TSPA-SR. However, the evaluation of importance of these conservatisms to dose estimates is qualitative in the conservatism activity. The NRC noted that the conservatism report and AMRs do not evaluate all the uncertainties and their importance to

dose. Thus the determination of importance to dose is subjective. The DOE agreed and stated that the unquantified uncertainties activity is intended to quantitatively evaluate the importance to dose estimates.

Regarding unquantified uncertainties, the DOE identified the key uncertainties and stated that it would evaluate the significance of these uncertainties to dose estimates. The DOE stated that currently the uncertainty review is non-Q and would be used for guidance to DOE staff/contractors for license application development. Subsequent revisions to the AMRs would be developed in accordance with guidance that is developed. The DOE stated that the evaluation complements, but does not replace, TSPA for the Site Recommendation. The NRC raised an issue regarding the QA status of the uncertainty analyses in light of the fact that these analyses are providing important guidance for license application development. The DOE responded that the present uncertainties activities will only be used to provide insight to develop guidance for treatment of uncertainties to support license application.

3) Total System Performance Assessment

The DOE provided an overview of how TEF is being incorporated into the TSPA (see "Thermal Effects on Flow - Representation in the Total System Performance Assessment" presentation given by Nicholas Francis).

The DOE stated that thermally-enhanced percolation flux above the drift crown and the in-drift thermodynamic environment are the two TSPA process level models pertinent to TEF. The NRC commented that the thermohydrologic abstractions do not include the mountain-scale coupled processes model results and large features such as faults. The DOE agreed that multi-scale model calculations used as input to TSPA do not consider effects from mountain-scale hydrologic processes or flow in faults.

Regarding the thermally enhanced percolation flux above the drift crown, the DOE stated that percolation flux at five meters above the drift crown was selected as input for the abstracted seepage model. The DOE stated that the thermal effects die out before the first climate stage, which is in approximately six hundred years. The DOE stated that thermodynamic variables are calculated for 610 locations representing waste package groups. The NRC questioned how the temperature and relative humidity responses calculated at 610 locations are reduced to the 400 waste package groups used in the corrosion models. The DOE stated the staff to answer that question were not present but that they would determine the answer. The NRC questioned whether the utilization of uncertainty in climate states represents or bounds all sources of uncertainty. The NRC asked whether the representation of variability and uncertainty in thermodynamic variables calculated from TEF models at the 610 locations needed to be propagated to other models (such as chemistry) or whether the current representation was appropriate. The DOE stated they believed the current abstraction appropriately represents variability and uncertainty.

The DOE stated that the variability and uncertainty in TEF do not have a large impact on TSPA-SR corrosion models as currently implemented. The NRC asked what the impact on the corrosion models would be with an increase in variability and uncertainty from TEF thermodynamic variables. The DOE responded that uncertainty resulting from heterogeneity can't be greater than uncertainty resulting from the no-backfill versus backfill example.

4) Technical Discussions - Subissue #1, Features, events, and processes related to thermal effects on flow

A summary of the current status of resolution was presented (see "Features, Events, and Processes for Thermal Effects on Flow and Evolution of the Near Field Environment" presentation given by Nicholas Francis). The DOE identified the NRC information needs from Revision 3 of the TEF IRSR. The DOE stated that the presentation would provide the basis for going to "closed-pending."

In its presentation, the DOE stated that the five open items would be addressed in the FEPs AMR revisions/changes and the update to the FEPs database. The NRC questioned whether the FEPs AMR updates would address all the NRC comments in Revision 3 of the IRSRs, including whether traceable references for the documentation of low-consequence calculations will be provided. The DOE stated that, in general, it believed the NRC comments were addressed, and it requested that the NRC review the updates and provide the DOE any additional comments. The DOE also addressed an NRC comment on regional hydrothermal activity. The DOE also provided a summary of the TEF and Evolution of the Near-Field Environment (ENFE) FEPs.

As a result of additional discussions, the NRC and DOE reached two agreements for Subissue #1 (see Attachment 1). With these two agreements, the NRC stated that Subissue #1 could be listed as "closed-pending".

5) Technical Discussions - Subissue #2, Thermal effects on temperature, humidity, saturation, and flux

The DOE addressed the nine open items listed in Revision 3 of the TEF IRSR (with the exception of Open Items 3, 4, and 9 as previously discussed).

<u>TEF Subissue 2, Open Item 1: Thermohydrologic Modeling for the Current Repository Design</u>:

The DOE discussed the basis for resolving Open Item #1 (see "Thermal Effects on Flow Subissue 2, Open Item 1: Thermohydrologic Modeling for the Current Repository Design" presentation given by Ernest Hardin and Tom Buscheck). The DOE stated that the presentation would provide the basis for closing the open item.

The DOE stated that multi-scale thermohydrologic model calculations have been conducted for the Enhanced Design Alternative II design with no backfill. The NRC inquired whether the design included ventilation. The DOE stated that the design included ventilation for the 50-year pre-closure period. The NRC further inquired whether the model included water removal resulting from ventilation and the DOE responded that it did not.

The DOE concluded that the thermohydrologic models incorporate relevant Enhanced Design Alternative II design features and, therefore, this open item can be closed.

<u>TEF Subissue 2, Open Item 2: Cold Trap Effects in the Multi-scale Thermohydrologic Model</u>:

The DOE discussed the basis for resolving Open Item #2 (see "Thermal Effects on Flow Subissue 2, Open Item 2: Cold Trap Effects in the Multi-scale Thermohydrologic Model" presentation given by Ernest Hardin and Tom Buscheck). The DOE stated that the presentation would provide the basis for going to "closed-pending" for this open item.

The DOE stated that it has identified the technical issues in modeling cold traps, key assumptions for cold traps for the Multi-scale Thermohydrologic Model, and is considering additional models, as appropriate, to represent cold trap effects in the Multi-scale Thermohydrologic Model. The DOE stated that the cold trap effects occur in emplacement drifts with water and latent heat transfer from warmer to cooler locations. The DOE stated that previous analyses indicated that drift-scale cold traps could produce condensate flux on cooler waste packages. The DOE stated: (1) it is developing a mountain-scale model to represent the repository-scale cold trap effect; (2) it is considering development of a detailed drift-scale thermohydrologic model to estimate the magnitude of the drift-scale cold trap effect; and (3) it may not incorporate the cold trap effect into TSPA unless it significantly changes the predicted dose. The NRC inquired what the DOE's standard is for a "significant" change in calculated dose. The DOE replied they would provide the NRC a response to the question.

TEF Subissue 2, Open Item 6: Data Support for the Ventilation Model:

The DOE discussed the basis for resolving Open Item #6 (see "Thermal Effects on Flow Subissue 2, Open Item 6: Data Support for the Ventilation Model" presentation given by Ernest Hardin). The DOE stated that the presentation would provide the basis for going to "closed-pending" for this open item.

The DOE presented an overview of the ventilation test. The DOE stated that the testing will be used to calibrate ventilation models based on ANSYS and Multiflux codes. During Phase 3 of the test, the DOE will simulate moisture removal by ventilation air using water injection and evaluate the effect on heat removal efficiency. The NRC questioned how the DOE would determine how much water needed to be added to adequately represent thermohydrologic coupling with the repository drift wall. The DOE stated that the ventilation test is designed to represent heat removal by ventilation air and is not designed to represent thermal-hydrologic coupling with the host rock at the drift wall.

Mr. Shettel (Nye County) questioned the evaporation and precipitation at the drift wall. The DOE responded that the precipitation occurs inside the rock and not at the drift wall. In addition, the DOE stated that calculations could be done to calculate the quantity of minerals precipitated. Mr. Shettel stated that Nye County has already done the calculations and they are presented on the Nye County webpage.

TEF Subissue 2, Open Item 5: Potential Heat Losses in Cross Drift Thermal Test:

The DOE discussed the basis for resolving Open Item #5 (see "Thermal Effects on Flow Subissue 2, Open Item 1: Potential Heat Losses in Cross Drift Thermal Test" presentation given by Mark Peters). The DOE stated that the presentation would provide the basis for closing the open item.

At the start of the presentation, the NRC asked about the status of monitoring mass and energy losses through the bulkhead of the drift-scale test. The DOE replied that a contractor proposal for monitoring losses through the bulkhead had been received and the DOE determined the proposal to not be feasible.

With respect to the cross-drift thermal test, the DOE stated that the potential for unmonitored mass and energy flow through the cross drift thermal test boundaries has been taken into account as identified in the Cross Drift Thermal Test Planning Report, Section 4.0. The DOE indicated that simulations to support test design showed that minimal mass or energy losses would occur through the boundaries of the cross drift thermal test. The NRC questioned whether these simulations were done using a stochastic representation of heterogeneity. The DOE said they were not. The NRC noted that incorporating heterogeneity into the simulations may provide different results related to potential losses through the test boundaries. The NRC stated that it would review the Cross-Drift Thermal Test Planning Report and provide the DOE comments, if any.

The DOE discussed the test design configuration. The DOE stated that the objectives of the cross drift thermal test include testing water shedding between drifts. The NRC questioned whether the water collection holes would be effective in collecting water and stated that capillary diversion needs to be taken into account. The DOE noted the NRC comment. The DOE stated that there might not be sufficient water for collection in the collection holes. The DOE acknowledged that conclusions on whether thermal seepage into emplacement drifts occurs could not be drawn solely on the basis of no water accumulating in the collection holes. Similarly, the DOE acknowledged that chemical analyses of liquid water cannot be undertaken if no water accumulates in the collection holes. The DOE stated that the Cross Drift Thermal Test Final Report is scheduled for December 2004 in the present baseline schedule.

Later in the meeting, Mr. Frishman (State of Nevada) raised three concerns about the cross drift thermal test. First, he noted that the current schedule for the test would not allow information to be used in the license application. Second, he stated that current repository design is based upon hypotheses that need to be tested. Finally, he indicated that the test would provide data to test three key hypotheses: (1) mobilized water would be shed between emplacement pillars; (2) there would be no penetration of the boiling isotherm by liquid; and (3) mobilized waters would have a benign chemistry with respect to engineered barrier performance. During the NRC review of the Cross-Drift Thermal Test Planning Report, the NRC will consider the State of Nevada's comments.

<u>TEF Subissue 2, Open Item 7: Data Uncertainty</u>:

The DOE discussed the basis for resolving Open Item #7 (see "Thermal Effects on Flow Subissue 2, Open Item 7: Data Uncertainty" presentation given by Bo Bodvarsson). The DOE stated that the presentation would provide the basis for going to "closed-pending" for this open item.

The NRC questioned how data uncertainty is propagated into TSPA because data uncertainty in calibrated properties used for current modeling represents only uncertainty in the boundary condition flux. The DOE responded by discussing ongoing efforts to account for other uncertainties in the calibrated properties model wherein the resulting calibrated properties would

properly include a measure of uncertainty along with the sets for high, mean, and low flux boundary conditions. The NRC responded that this would provide the needed measure of uncertainty but questioned whether this would be propagated further into TSPA. The DOE asked if the NRC has a suggestion for an efficient method to do so. The NRC suggested additional runs of the Multi-Scale Thermohydrologic Model, using important parameters at their 95% confidence (including parameters, such as thermal conductivity, not determined in the calibrated properties AMR), and binning these results into the abstraction along with results for the high, mean, and low boundary fluxes. Both the DOE and NRC acknowledge that a full analysis of parameter uncertainty would require an impossibly large number of model runs and that efforts need to focus on those parameters that have the largest effect on thermohydrologic model results and ultimately performance.

The DOE stated that to address this area, it would discuss: (1) uncertainty from spatially heterogeneous properties; (2) uncertainty in measured data; (3) propagation of uncertainty in inverse modeling; and (4) upscaling.

Regarding uncertainty from spatially heterogeneous properties, the DOE stated that it is most important for site-scale flow and transport. The DOE further stated that heterogeneity within individual layers is incorporated for specific problems (e.g., seepage into drift, perched water bodies).

Regarding uncertainty in measured data, the DOE stated that measured data are upscaled to the unsaturated zone model gridblock scale common to both mountain scale simulations and inverse modeling calibration studies. The DOE further stated that upscaling is only necessary for certain parameters. The NRC suggested the methods used for upscaling be summarized and documented.

The DOE stated that measurement errors are taken into account in iTOUGH. The NRC commented that the AMR currently available to the NRC does not take into account heat dissipation probe information. The DOE stated that the future AMR will incorporate it.

Regarding propagation of uncertainty in inverse modeling, the DOE stated that iTOUGH2 utilizes a statistical minimization routine and automatic optimization algorhythm to yield best matches to the observed data. The analysis yields a statistical evaluation of the goodness of fit and the relative importance of all relevant input parameters (including the ten most sensitive ones). The DOE stated that it was going to start submitting the iTOUGH2 output on sensitivity and uncertainties of parameters to the technical database. The NRC commented that this would be a good idea.

The NRC noted that the various property sets used for thermohydrologic modeling were determined by the DOE to be equally valid based on comparisons to temperature data from the drift scale test, although saturations and fluxes obtained using these various property sets were significantly different. The NRC questioned whether additional comparisons of modeled versus measured saturations were to be done and if these comparisons would take into account uncertainties such as losses through the thermal bulkhead and in saturation measurements using ERT, GPR, and neutron probes. The DOE responded that these comparisons were being made.

TEF Subissue 2, Open Item 8: Model Uncertainty:

The DOE discussed the basis for resolving Open Item #8 (see "Thermal Effects on Flow Subissue 2, Open Item 8: Model Uncertainty" presentation given by Bo Bodvarsson). The DOE stated that the presentation would provide the basis for going to "closed-pending" for this open item.

The DOE stated that three types of uncertainties are considered in the thermohydrologic models (1) property/parameter, (2) conceptual model, and (3) numerical model uncertainty. The DOE then discussed flow conceptualization under ambient and thermal conditions. The DOE indicated there is uncertainty in conceptual models and said this uncertainty is being evaluated using alternative conceptual models such as discrete fracture models. The DOE stated that this evaluation would be discussed in the Unsaturated Zone Flow and Transport PMR, Rev. 00, ICN 02.

TEF Subissue 2, Overall Status

As a result of additional discussions, the NRC and DOE reached 13 agreements for Subissue #2 (see Attachment 1). With these 13 agreements, the NRC stated that Subissue #2 could be listed as "closed-pending."

6) Public Comments

There were no general public comments other than those discussed above.

C. William Reamer	Dennis R. Williams
Deputy Director	Deputy Assistant Manager
Division of Waste Management	Office of Licensing & Regulatory Compliance
Nuclear Regulatory Commission	Department of Energy