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6220 Culebra Road • San Antonio, Texas, U.S.A. 78228-5166
(210) 522-5160 • Fax (210) 522-5155

July 30, 2003
Contract No. NRC-02-02-012
Account No. 20.06002.01.101

U.S. Nuclear Regulatory Commission
ATTN: Dr. Mysore S. Nataraja
Division of Waste Management
Two White Flint North
Mail Stop 7-C6
Washington, DC 20555

Subject: Repository Design and Thermal-Mechanical Effects Key Technical Issue Intermediate Milestone No. 20.06002.01.101.380, Review of Response to Agreement RDTME.3.01

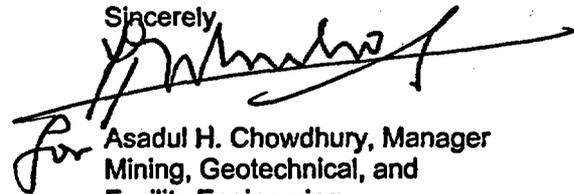
Dear Dr. Nataraja:

Attached is the Center for Nuclear Waste Regulatory Analyses document entitled "NRC Review of DOE Documents Pertaining to Key Technical Issue Agreements (RDTME 3.01)." This document fulfills the requirements for the subject milestone, which is due July 31, 2003.

This report summarizes the CNWRA review of the CRWMS M&O report, "In Situ Field testing Processes", the Bechtel SAIC report, "Responses to RDTME 3.01 Request for Additional Information received February 28, 2002", and data files MO0104SPATEM00.001 ESF Temperature and Humidity Monitoring Record, MO0107SPATEM00.002 Summary of ESF Temperature and Humidity Monitoring Record, and MO0203SPAESF00.003 ESF Temperature and Humidity Monitoring Record, received in response to the NRC request for additional information for NRC-DOE Agreement RDTME 3.01. The staff also considered the changes to the drift support design presented at the NRC-DOE Technical Exchange on Repository Design and Thermal-Mechanical Effects (May 6-8, 2003). In addition, DOE has indicated that the corrosion of ground support materials will be considered in the analysis of ground support performance and a plan for monitoring, inspection, and maintenance of the ground support will be developed. The staff reviewed the DOE supplied information and have concluded that the information provided is sufficient to close the agreement.

If you have any questions concerning this milestone, please contact me at 210-522-5151 or Goodluck Ofoegbu at 210-522-6641.

Sincerely


For Asadul H. Chowdhury, Manager
Mining, Geotechnical, and
Facility Engineering

AHC:cap
Attachment

cc:	D. DeMarco	A. Csontos	A. Ibrahim	D. Gute	<u>Letter only</u>
	E. Whitt	J. Firth	T. Bloomer	B. Dasgupta	M. Leach
	B. Meehan	J. Greeves	D. Brooks	S. Hsiung	CNWRA Directors
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Washington Office • Twinbrook Metro Plaza #210
12300 Twinbrook Parkway • Rockville, Maryland 20852-1606

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**NRC REVIEW OF DOE DOCUMENTS PERTAINING TO
KEY TECHNICAL ISSUE AGREEMENTS (RDTME 3.01)**

Prepared for

**U.S. Nuclear Regulatory Commission
Contract NRC-02-02-012**

Prepared by

**D. Dunn
R. Fedors
G. Ofoegbu**

**Center for Nuclear Waste Regulatory Analyses
San Antonio, Texas**

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NRC Review of DOE Documents Pertaining to Key Technical Issue Agreements

The U.S. Nuclear Regulatory Commission (NRC) goal of issue resolution during the 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 license application for review. Resolution by the NRC staff during pre-licensing does not prevent anyone from raising any issue for NRC consideration during the licensing proceedings. Furthermore, resolution by the NRC staff during pre-licensing does not prejudice what the NRC staff evaluation of that issue will be after its licensing review. Issues are resolved by the 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 one NRC/DOE agreement made during the Repository Design and Thermal-Mechanical Effects (RDTME) Technical Exchange and Management Meeting.¹ After reviewing DOE submitted information² to address RDTME Agreement 3.01 NRC requested additional information from DOE needed to complete the agreement.³ DOE has submitted additional information to the NRC.^{4,5}

Repository Design and Thermal-Mechanical Effects Agreement RDTME.3.01

Wording of the Agreement: Provide the technical basis for the range of relative humidities, as well as the potential occurrence of localized liquid phase water, and resulting effects on ground support systems. The DOE will provide the technical basis for the range of relative humidity and temperature, and the potential effects of localized liquid phase water on ground support systems, during the forced ventilation preclosure period, in the *Longevity of Emplacement Drift Ground Support Materials Analysis/Model Report*, ANL-EBS-GE-000003 Rev. 01 (CRWMS M&O, 2000a), and Revision 1 of the *Ventilation Model Analysis/Model Report*, ANL-EBS-MD-000030 (CRWMS M&O, 1999), analysis and model reports. These are expected to be available to NRC in September and March 2001, respectively.

¹Reamer, C.W. "NRC/DOE Technical Exchange and Management Meeting on Repository Design and Thermal-Mechanical Effects (February 20, 2001)." Letter (February 28) to S. Brocoum, DOE. Washington, DC: NRC. 2001.

²Brocoum, S.J. "Transmittal of Reports and Data Addressing Key Technical Issues (KTI)." Letter (June 28) to C.W. Reamer, NRC. Las Vegas, Nevada: DOE. 2001.

³Schlueter, J.R. "Repository Design and Thermal-Mechanical Effects Key Technical Issue Agreement." Letter (February 28) to S.J. Brocoum, DOE. Washington, DC: NRC. 2002.

⁴Ziegler J.D. "Transmittal of Report Addressing Key Technical Issues (KTI)." Letter (April 26) to J.R. Schlueter, NRC. Las Vegas, Nevada: DOE. 2002.

⁵Ziegler J.D. "Key Technical Issue (KTI) Repository Design and Thermal-Mechanical Effects (RDTME) 3.01" Letter (May 13) to J.R. Schlueter, NRC. Las Vegas, Nevada: DOE. 2003.

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Basis for the Agreement: The analysis of emplacement-drift stability previously provided by DOE to support its site recommendation (CRWMS M&O, 2000b) did not include consideration of any degradation of the ground support system during the preclosure period. DOE asserted in the *Longevity of Emplacement Drift Ground Support Materials Analysis/Model Report Rev. 01* (CRWMS M&O, 2000a) that the carbon steel ground support system (which consisted of steel sets and occasional rock bolts) would not experience significant corrosion for 300 years. DOE, therefore, proposed that the emplacement drift ground support would not need planned maintenance during a preclosure period of up to 175 years, and that planned maintenance would be needed only if the preclosure period were to be extended to last up to 300 years (CRWMS M&O, 2000c). The assertion that the ground support system would not experience significant corrosion during the preclosure period was based on an argument that the corrosion rates would be negligible because the relative humidity within the emplacement drifts would be in the range of 1–40 percent, which is below the critical relative humidity for humid-air corrosion. The information requested in RDTME Agreement 3.01 is needed to establish an acceptable technical basis for excluding corrosion effects from consideration in the design of a maintenance free ground support system.

NRC Review: The DOE submitted two documents [*Longevity of Emplacement Drift Ground Support Materials Analysis/Model Report Rev. 01* ICN 01(CRWMS M&O, 2001a) and the KTI Letter Report: *Effect of Forced Ventilation on Thermal-Hydrologic Conditions in the Engineered Barrier System and Near Field Environment*] to address Key Technical Issue Agreement RDTME 3.01. After review of these documents, the NRC requested additional information necessary to evaluate the information provided by the DOE to address KTI agreement RDTME 3.01.⁶ The additional information needed is listed as follows.

1. Provide information on the time interval over which the relative humidities in the Exploratory Studies Facility (ESF) Main Drift were measured.
2. Provide the information on the effects of external environmental conditions on the relative humidity in the ESF Main Drift.
3. Provide an assessment of the effects of localized liquid phase water on the ground support systems and estimations of the frequency and location of localized liquid phase water.
4. Provide the technical basis for why the effects of mixed salts are not considered in the corrosion assessment of the ground support materials.
5. Provide the technical basis for not including the possibility that water may reside in the tight crevices between the drift wall and the steel sets used for ground support.
6. Provide the technical basis for why the presence of a water film between the drift support materials and the drift wall is not considered in the assessment of microbial activity

⁶Ziegler J.D. "Key Technical Issue (KTI) Repository Design and Thermal-Mechanical Effects (RDTME) 3.01" Letter (May 13) to J.R. Schlueter, NRC. Las Vegas, Nevada: DOE. 2003.

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Since the NRC additional information needed letter, DOE has modified its proposed ground support design for the emplacement drifts; based on information presented by DOE at the DOE/NRC Technical Exchange on Repository Design and Thermal-Mechanical Effects Key Technical Issue, which was held in Las Vegas on May 6–8, 2003.⁷ The ground support system for the emplacement drifts in the modified design would consist of friction rock bolts (Grade 316 stainless steel Split sets/Swellex bolts) with stainless steel thin-wall Bernold-style perforated surface sheets.⁸ The DOE strategy for the design of a ground support system for the emplacement drifts as described by Board (2003), included in a letter dated April 4, 2003,⁹ consists of four steps as follows. First, develop an initial design using industry practice based on empirical relationships. Second, evaluate the design through numerical modeling; considering an appropriate range of rock mass properties, loading combinations, environmental conditions, and the repository operational requirements. Third, estimate corrosion potential and life expectancy of the ground support. Fourth, develop monitoring, inspection, and maintenance programs for the emplacement drifts as the design progresses from the conceptual to detailed phases.

The DOE response to the requested information included the *In-Situ Field Testing of Processes Analysis/Model Report* (CRWMS M&O, 2001b) and source data files. The DOE responses to the NRC additional information request are individually evaluated.

1. Provide information on the time interval over which the relative humidities in the Exploratory Studies Facility (ESF) Main Drift were measured.

The DOE has provided the requested information in the data files MO0104SPATEM00.001 and MO0107SPATEM00.002. The relative humidity was recorded every hour for a period of 6.5 months. Analysis of the data indicate that the relative humidity is typically in the range of 10 to 40 percent. Occasionally, the relative humidity was above 50 percent; however, the duration of these events were less than 24 hours. The information contained in the data files provided by the DOE is consistent with the assumed relative humidity in the *Longevity of Emplacement Drift Ground Support Materials Analysis/Model Report*, Rev. 01 ICN 01 (CRWMS M&O, 2001a).

2. Provide the information on the effects of external environmental conditions on the relative humidity in the ESF Main Drift.

The DOE provided information in the data file MO0203SPAESF00.003, a comparison of selected surface and underground relative humidity values intermittently over a 6-month period for two selected stations. No temperature data from the surface station was included

⁷Schlueter, J.R., "NRC/DOE Technical Exchange on Repository Design and Thermal-Mechanical Effects (May 6–8, 2003)." Letter (May 22) to J.D. Ziegler, DOE. Washington, DC: NRC. 2003.

⁸Duan, F. and M. Board. "Ground support Studies and Design Status." Presented at the NRC/DOE RDTME Technical Information Exchange." Las Vegas, Nevada. May 6-8, 2003.

⁹Ziegler, J.D., "Transmittal of a Report Addressing the Strategy for Resolution of Geomechanically-Related Repository Design and Thermal-Mechanical Effects (RDTME) Key Technical Issue (KTI) Agreements." Letter (April 4) to J.R. Schlueter, NRC. Las Vegas, Nevada: DOE. 2002.

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in the DOE submittal. The DOE report noted the prominent dampening at underground locations of ground surface diurnal fluctuations in relative humidity. This dampening of relative humidity fluctuations underground was probably due to the dampening of diurnal temperature fluctuations underground. The DOE also identified one period of elevated underground relative humidity that was correlated with high ground surface relative humidity, likely corresponding to a storm event. The DOE report concludes that the effects of external environmental conditions on the relative humidity in tunnels and drifts "are negligible, relative to the effects on corrosion rates."

The NRC was also concerned with long term variations in external conditions and their effect on underground environmental conditions. The longer term records from meteorological stations on Yucca Mountain (e.g., CRWMS M&O, 2000d) could provide a better basis for typical relative humidity conditions at Yucca Mountain than the short term records provided in MO0203SPAESF00.003. For example, it is not clear if the average for the year 2000 of 31.1 percent relative humidity from the ESH/IAM Site 1 data provided in MO0203SPAESF00.003 reflects typical conditions at Yucca Mountain. Precipitation records from the nearby Nevada Test Site meteorological station (4JA) suggest that the August 2000 to December 2000 was a drier period than normal for those months.

The assessment of the effect of external environmental conditions on underground relative humidity, however, may not require further analysis depending on two other aspects. One, the magnitude of the temperature increase caused by the emplacement of waste packages has not been factored into the analysis. The relative humidity should decrease because of the heat generated by the waste. Two, the relative humidity threshold for corrosion of the ground support system, specifically the effect on corrosion of intermittent periods of time when that threshold is exceeded. For most metals, including steel, the critical relative humidity for humid air corrosion is approximately 60 percent. Information provided by the DOE shows that the relative humidity inside the emplacement drifts should be maintained below the critical relative humidity for humid air corrosion and external environmental conditions should not significantly alter the relative humidity inside the emplacement drifts.

3. Provide an assessment of the effects of localized liquid phase water on the ground support systems and estimations of the frequency and location of localized liquid phase water.

The DOE cited two relevant results:

- i. observation of a localized damp feature and drying profiles in niches along the ESF Main Drift, and
- ii. water potential measurements in boreholes along the Enhanced Characterization of the Repository Block drift

These observations along with the assumption that the contact between steel sets and the wallrock was similar to fractures in the wallrock led to the DOE conclusion that the engineered materials in drifts would be in a dry environment. For the observation of a localized damp feature, the DOE has reported that a small wet feature was observed in Niche 3566 after excavation. The feature dried up in hours and no other wet features were observed. This observation supports the inference that the evaporation rate driven by

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ventilation is much larger than localized percolation rates. The observation of the wet feature also supports the conclusion that exposed rock faces will dry out quickly. Based on long term water potential measurements in the alcoves and Enhanced Characterization of the Repository Block drift, the DOE evaluation indicates that dry out zones extend 2 to 3 meters into the rock. The DOE report also notes that the emplacement drifts will be hotter than the existing conditions in the tunnel, drift, and alcoves. The higher temperatures will cause an additional reduction in the relative humidity of the air mass in the emplacement drifts.

The observed drying of the localized damp feature and the water potential measurements support the DOE analysis that indicates ventilation of the emplacement drifts would deter the formation of liquid water between the steel sets and the drift wall. The ground support system in the latest repository design has changed, however, from steel sets to rock bolts with a perforated metal drift liner. Depending on the length of rock bolts used, many of the bolts may extend beyond the dry out zone for a significant time period during the preclosure period. Furthermore, the perforated metal liner could decrease the extent of the dry out thickness. The humidity condition around the bolts is not necessarily determined by the information provided by DOE regarding the potential dryness of the emplacement drifts and the surrounding rock. The DOE has indicated that the conditions surrounding the rock bolts will be similar to the condition of fractures which are drier than the conditions of the rock matrix. To assess the environmental conditions surrounding the rock bolts a definition of "dry" is needed.

The rock bolts will be in complete or partial contact with the rock matrix. Thus, the water content and relative humidity of the rock mass are relevant to the determination of the environmental conditions surrounding the rock bolts. DOE properly infers that the relative humidity of the air mass in the drifts should not be used to estimate the relative humidity adjacent to engineered materials in direct contact with the wallrock. Water potential measurements infer water contents in the rock matrix. There are no measurements of water potential, water content, or relative humidity in fractures at Yucca Mountain. DOE uses water potential data to infer a dryout thickness. Data from CRWMS M&O (2001b) indicate that the "driest" measured value in the wallrock was approximately -30 bars. This value of water potential can be shown to correspond to a relative humidity of approximately 98 percent in pore spaces using the standard Kelvin equation for porous media, which is the basis for psychrometers used at Yucca Mountain to measure water potential. Conceptually, the first few centimeters of the matrix probably have a fairly low (large negative value) water potential, such that the relative humidity in the pore space is significantly lowered. Beyond the first few centimeters of depth into the wallrock, the pore space relative humidity is likely high. In the rock matrix near large aperture fractures, the water potential is also likely low. For most of the fractures, the water potential is probably slightly lower than the adjacent matrix, but not enough to lower the relative humidity significantly.

Based on the information provided by the DOE, it is not clear that the environment surrounding rock bolts would be maintained at a low relative humidity. The DOE has indicated that the need to study the potential impacts of localized liquid phase water on the various ground support materials will be assessed and a strategy for monitoring, inspection and maintenance will be developed as needed. The effect of localized high humidity environments on stability of the engineered support materials should also be assessed. In

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particular, the analysis of the ground support design should include the effects of rock bolt corrosion.

4. Provide the technical basis for why the effects of mixed salts are not considered in the corrosion assessment of the ground support materials.

The DOE has indicated that the effects of mixed salts was not performed because credit for the performance of ground support systems is limited to the preclosure period. Assessment of the effects of mixed salts on the deliquescence point will be provided in the responses to NRC/DOE KTI Agreements ENFE 2.13 and 2.15. The formation of mixed salts that may deliquesce at lower relative humidity and promote aqueous corrosion of the rock bolts will be evaluated using the information generated to fulfil ENFE 2.13 and 2.15. In addition, the DOE analysis of ground support design and the strategy for monitoring, inspection, and maintenance of the ground support materials should consider the effects of any mixed salts that are expected to form in the vicinity of the rock bolts during the preclosure period.

5. Provide the technical basis for not including the possibility that water may reside in the tight crevices between the drift wall and the steel sets used for ground support.

The DOE assessment of the formation of localized liquid phase water is described in item #3. Data provided by the DOE suggests that ventilation leads to dry out extending into the rock. Dry out of the rock would likely reduce the possibility for the formation of water in the crevices between any steel sets and the rock. The recent change in the DOE proposed design for emplacement drift ground support, however, raises additional questions regarding the range of environmental conditions to which the rock bolts will be exposed. It is unclear if the information provided by the DOE can be used to estimate the environmental conditions controlling the corrosion of rock bolts. In addition, it is not clear if the rock bolts would become conduits for the transfer of water into the excavated drift or undergo periodic wetting and dryout which may alter the concentration of dissolved species in the water contacting the rock bolts.

Based on the information provided by the DOE, it is not clear ventilation would prevent the possibility that water may reside in the crevices surrounding rock bolts. The DOE has indicated, however, that the potential impacts of localized liquid phase water on the various ground support materials will need to be assessed. The environment in contact with the rockbolts should be included in the DOE strategy for monitoring, inspection and maintenance of the drift support materials.

6. Provide the technical basis for why the presence of a water film between the drift support materials and the drift wall is not considered in the assessment of microbial activity.

The DOE response indicates that microbial activity requires the presence of liquid water which is assessed in the response to item #3. Based on the information provided by the DOE, it is not clear that ventilation would prevent water contact with the rock bolts that may lead to microbial induced corrosion. The DOE has indicated, however, that the potential impacts of localized liquid phase water on the various ground support materials will need to be assessed.

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Additional Information Needs: No additional Information is necessary.

Status of Agreement: Taking into consideration that the DOE has provided information on the relative humidity measurements, indicated that the effect of mixed salts will be addressed in the responses to NRC/DOE KTI Agreements ENFE 2.13 and 2.15, and developed a design strategy for the emplacement drift ground support that includes providing a monitoring and maintenance plan for the emplacement drifts, NRC considers this agreement as complete. Recent information presented in the Repository Design and Thermal Mechanical Effects technical information exchange¹⁰ indicates that the design of the emplacement drift support system has changed and steel sets will be replaced by stainless steel rock bolts. The information provided by DOE to address RDTME 3.01 does not include any discussion of the DOE approach for including the corrosion of rock bolts in its assessment of the ground support performance. DOE, however, indicated that potential ground support corrosion would be included in its ground support analysis and would be considered by DOE in developing a monitoring and maintenance plan for the emplacement drifts. DOE also indicated that this information (i.e., corrosion of ground support materials, the effect of such corrosion on ground support performance, and how this effect is considered in the monitoring and maintenance plan for emplacement drifts) will be provided in subsequent reports that would be available to NRC prior to any license application.

REFERENCES

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¹⁰Schlueter, J.R. "NRC/DOE Technical Exchange on Repository Design and Thermal-Mechanical Effects (May 6-8, 2003)." Letter (May 22) to J.D. Ziegler, DOE. Washington, DC: NRC. 2003