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QA: N/A

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TRANSMITTAL OF REPORT ADDRESSING KEY TECHNICAL ISSUE (KTI) AGREEMENT ITEM TOTAL SYSTEM PERFORMANCE ASSESSMENT AND INTEGRATION (TSPAI) 3.03

This letter transmits the report entitled, *Response to TSPAI Agreement 3.03*, to satisfy the subject KTI agreement. KTI Agreement Item TSPAI 3.03 addresses the technical basis for the U.S. Department of Energy's (DOE) representation of stress corrosion cracking (SCC) in the drip shield and waste package. The agreement is as follows:

> TSPAI 3.03 - "Provide the technical basis for crack arrest and plugging of crack openings (including the impact of oxide wedging and stress redistribution) in assessing the impact of SCC of the drip shield and waste package in revised documentation (ENG1.1.2 and ENG1.4.1)."
>
> "DOE will provide the technical basis for crack arrest and plugging of crack openings (including the impact of oxide wedging and stress redistribution) in assessing the stress corrosion cracking of the drip shield and waste package in an update to the Stress Corrosion Cracking of the Drip Shield, Waste Package Outer Barrier, and the Stainless Steel Structural Material AMR (ANL-EBS-MD-000005) in accordance with the scope and schedule for existing agreement item CLST 1.12."

Sensitivity studies were performed to show the relative importance of specific representation of drip shield crack openings to meeting the individual protection or groundwater protection performance objectives. These sensitivity studies show that the specific representation of drip shield crack openings are not important to the determination of whether the individual protection or groundwater protection performance objectives would be met.

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The technical basis for the representation of stress corrosion cracks, including the effects of crack arrest or plugging of crack openings (including the impact of oxide wedging and stress redistribution) are not considered important to performance with regard to the postclosure performance objectives. Thus, the enclosed risk information is proposed as an alternative approach to meeting this agreement and for the closure of KTI Agreement Item TSPAI 3.03 as discussed at the April 15-16, 2002, U.S. Nuclear Regulatory Commission/DOE Technical Exchange and Management Meeting on KTIs.

Agreement Items Container Life and Source Term 1.12 and General (GEN) 1.01(09), (10), and (21) are associated with drip shield SCC. These agreements are explicitly referenced in KTI Agreement Item TSPAI 3.03, or have been mapped to this agreement because of the similarity in subject (e.g., drip shield SCC). Although similar arguments can be made to address these agreements, the proposed DOE resolution in this letter does not explicitly address these agreements, except for the applicable portion of KTI Agreement Item GEN 1.01(21). The portion of GEN 1.01(21) addressed by this letter is the potential for SCC initiation/arrest in the waste package. Dispositioning of the remaining agreements will be included in the Fiscal Year (FY) 2003 and FY 2004 KTI planning efforts.

This letter contains no new regulatory commitments. Please direct any questions concerning this letter and its enclosure to Mark C. Tynan at (702) 794-5457 or Timothy C. Gunter at (702) 794-1343.

William Boyle for

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OL&RC:TCG-1326

Enclosure:
Response to TSPAI Agreement 3.03

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RESPONSE TO TSPAI AGREEMENT 3.03

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Peter Swift, Manager, Performance Assessment Scope and Strategy — Date: 26 June 02

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ENCLOSURE

Enclosure
Response to TSPAI Agreement 3.03

Background

Key Technical Issue (KTI) agreement Total System Performance Assessment and Integration (TSPAI) agreement 3.03 relates to the technical basis for crack arrest and plugging of crack openings (including the impact of oxide wedging and stress redistribution) in assessing the stress corrosion cracking of the drip shield and waste package. The underlying issue is the representation of the crack in estimating flow of water through a crack and transport of radionuclides in this flow.

NRC Initial Comments

In the August 2001 TSPAI Technical Exchange (Reamer, C. W. and Gil, A. V. 2001), the NRC commented that the DOE model abstraction for the transport of water through stress corrosion cracks in the drip shield and diffusive transport of radionuclides through the stress corrosion cracks in the waste packages assumes that the quantity of water that is transported through cracks in the titanium alloy drip shield is limited by diffusion. Therefore stress corrosion cracking of the drip shield has been excluded as a feature, event or process (FEP) on the basis of low consequence because water transport though cracks in the drip shield will not significantly increase the quantity of water contacting the waste packages and waste forms. The NRC noted that the DOE assumption of diffusive transport of radionuclides with the exclusion of advective transport relies on stress corrosion crack geometries that will remain tight for thousands of years. The NRC concluded that the tight geometry of stress corrosion cracks is based on unsupported assumptions and therefore DOE needs to provide the technical basis for the tight crack geometries that prevent advective transport through stress corrosion cracks in the drip shield.

DOE Initial Response

The drip shield degradation component of the TSPA model estimates the degree of breaching of the drip shield over time. This information is used to estimate the fraction of seepage incident on the drip shield that is transmitted through to the waste package. Previous analyses using fracture mechanics have shown that the stress corrosion crack openings in the drip shield and waste package are very "tight" (CRWMS M&O 2000a, Section 6.5.5). The cracks in the drip shield due to rockfall (CRWMS M&O 2000b, Section 6; CRWMS M&O 2000a, Section 6.5.5) and hydrogen induced cracking (CRWMS M&O 2000c, Section 6.3.4) are self-limiting and remain tight. These tight cracks are expected to be plugged by corrosion products and mineral precipitates. Recent analyses have shown that stress corrosion cracks are expected to be plugged by calcite within a few decades (BSC 2001a, Tables 6-3 and 6-5); thus very limited water flow is expected through the plugged stress corrosion cracks. Because such plugged stress corrosion cracks would not affect the intended function of the drip shield (i.e., diversion of dripping water), the drip shield stress corrosion cracking (SCC) was screened out and not modeled in the TSPA.

The TSPA-Site Recommendation (CRWMS M&O 2000d) assumes diffusion is the dominant transport process for radionuclide release through the plugged stress corrosion cracks in the waste package. It is acknowledged that the screening arguments for FEP 2.1.03.10.00 (Container Healing) need to be updated to incorporate the latest analysis for the stress corrosion crack plugging and to be consistent with the TSPA analysis. The waste package FEPs Analysis/Model Report (CRWMS M&O 2001) will be revised to update the screening argument.

Enclosure 1
Response to TSPAI Agreement 3.03

KTI Agreement

TSPAI.3.03 - Provide the technical basis for crack arrest and plugging of crack openings (including the impact of oxide wedging and stress redistribution) in assessing the impact of SCC of the drip shield and waste package in revised documentation (ENG1.1.2 and ENG1.4.1). DOE will provide the technical basis for crack arrest and plugging of crack openings (including the impact of oxide wedging and stress redistribution) in assessing the stress corrosion cracking of the drip shield and waste package in an update to the Stress Corrosion Cracking of the Drip Shield, Waste Package Outer Barrier, and the Stainless Steel Structural Material AMR (ANL-EBS-MD-000005) in accordance with the scope and schedule for existing agreement item CLST.1.12.

Status of Agreement(s)

The DOE TSPA sensitivity studies provide insight regarding the role of the drip shield as a barrier to meet the 10 CFR Part 63 individual dose standard. The studies show the sensitivity of the estimate of mean annual dose to the representation of breaches in the drip shield. The study results indicate that even with the drip shield assumed to be completely breached (i.e., completely open with respect to transmission of water) at the time of emplacement, the associated increase in mean annual dose is small. Thus, it can be concluded that the particular representation of stress corrosion cracks in the drip shield has little effect on overall repository performance. The information regarding crack growth and plugging of cracks in the drip shield that would be developed in accordance with agreement TSPAI 3.03 is not important to showing the individual and groundwater protection requirements would be met. The following risk information is being provided to NRC as an alternate basis for closure of TSPAI 3.03.

Although TSPAI 3.03 includes stress corrosion cracking of the drip shield and waste package, based on the NRC's initial comment, the DOE proposed resolution only addresses drip shield SCC. With the drip shield in place, there is no stress corrosion cracking of the waste package during the 10,000 year compliance period. Corrosion induced as a result of mechanical damage to the waste package will be addressed in Repository Design and Thermal Mechanical Effects 3.18.

Definition

Significant - an increase in magnitude of the expected annual dose, as a result of the omission of a FEP or the omission or failure of an engineered barrier, that is more than a small fraction of the numerical limits associated with the postclosure performance objectives in 10 CFR 63.113.

DOE's Proposed Resolution

DOE has performed TSPA sensitivity studies to gain insight regarding the importance of drip shield performance to meeting the 10 CFR Part 63 individual dose standard. The sensitivity studies evaluated the impact of changes in the representation of breaches in the drip shield. The TSPA model used for the sensitivity studies is based on the TSPA model used for the Final Environmental Impact Statement (FEIS) supplemental analyses (BSC 2001a, Section 5.2, p. 6). Sensitivity studies utilizing this model are fully probabilistic, employing a Monte Carlo sampling approach. The key difference between this TSPA model and the FEIS supplemental model is that each realization arbitrarily includes early failure of one package in every realization. This approach results in a factor of four increase in the estimate of mean annual dose during the early period.

Two studies were considered. The first study examined the impact of an aggressive drip shield corrosion rate. The general corrosion rate of the drip shield material was enhanced by a factor of more than five[1]. This enhanced rate is outside the range of uncertainty represented in the reference model and is chosen to test the sensitivity to extreme and unrealistic conditions. As shown in Figure 1 by the degraded drip shield performance curve, even at the higher corrosion rate, none of the drip shields are expected to fail due to corrosion before 10,000 years. As a result, the estimate of mean annual dose in the first 10,000 years is not affected.

These results are consistent with the TSPA-Site Recommendation model results (CRWMS M&O 2000e Section 5.3.3.1, p. 5-35) in that the details of the drip shield performance model do not play a significant role in the estimate of mean annual dose over the range investigated.

The second study considers a more extreme representation of drip shield degradation in which the barrier function of the drip shield is assumed to be completely breached at the time of permanent closure. Figure 1 shows that with the drip shields neutralized, an increase in the estimated mean annual dose occurs due to the fact that the drip shields provide no effective barrier to water contacting the waste packages in the study. The associated increase in mean annual dose is calculated to be less than 0.001 mrem/year due to an increased rate of release of radionuclides from the waste packages that are breached. These results indicate that breaching of the drip shield due to SCC or other degradation modes does not have a significant impact on the estimate of mean annual dose.

The individual protection argument for a neutralized drip shield is expected to also apply to the groundwater protection performance objective because the factors that limit the level of radioactivity in groundwater are the same as those that affect groundwater migration of radionuclides (i.e., degradation of engineered barriers) for the individual protection performance objective. Previous studies have shown that the groundwater concentrations due to the maximum mean gross alpha activity and combined radium-226 and radium-228 that might be released from the repository would be well below background levels and the regulatory limits (BSC 2001c, Tables 6-1 and 6-2, p. 10). For the dose due to combined beta and photon emitters, Figure 1 shows that the total dose considering all pathways is well below the regulatory limit. Hence, the groundwater protection limits, which consider a more limited pathway, can be expected to be below the regulatory limit based on the individual protection argument.

Consequently, the arguments regarding crack growth and plugging of cracks are not considered to have a significant bearing on DOE's ability to show that the individual protection performance objective can be met. Accordingly, the information that would be provided in this regard in response to agreement TSPAI 3.03 does not have a high priority for the safety case DOE would

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[1] The median of the measurements of general corrosion rate in weight-loss experiments is about 0.025 microns/year and the 95th percentile value is about 0.12 microns/year (CRWMS M&O 2000c, Section 6.5.4, p 59). The measured corrosion rate is corrected for deposition of silicates during experiment by adding a factor that averages 0.03 microns/year. The approach for this analysis is to utilize the 95th percentile of the uncorrected measurements and to add a correction of 0.17 microns/year to ensure the analysis goes to the extreme of the correction factor. The effective general corrosion rate is 0.29 microns/year, more than a factor of ten greater than the median of the measured values and more than a factor of five greater than the median corrected value.

prepare for the license application. Therefore, these results are provided as an alternative approach to satisfying this agreement.

Quality Assurance

The sensitivity studies conducted for this report are scoping studies that provide information to support management decisions. The sensitivity studies use methods analogous to those used in the TSPA-Site Recommendation to evaluate the relative significance of alternative models and parameters in support of a license application. The results of the studies are intended to provide insights, not analytical input, and are supported by appropriate documentation. The components of the TSPA model used in the studies are being updated as appropriate and validated under the OCRWM Quality Assurance Program. The studies applied data, models and software identical or similar to those used for the revised supplemental analyses for the site suitability evaluation including the Final Environmental Impact Statement Supplemental Analysis, are traceable, and confirm DOE's understanding of the repository system contained in the Site Recommendation supporting documents. The studies described in this report were performed using the GoldSim Code V7.17.200 (BSC 2001c).

Applicable Requirements

- 10 CFR 63.114(g) Provide the technical basis for models used in the performance assessment such as comparisons made with outputs of detailed process-level models and/or empirical observations (e.g., laboratory testing, field investigations, and natural analogs)
- Draft YMRP, Revision 2: Acceptance Criterion 2 - Data are sufficient for model justification

Related KTI Agreements

The following agreements are associated with drip shield stress corrosion cracking. These agreements are explicitly referenced in TSPAI 3.03 or have been mapped to this agreement because of the similarity in subject (e.g., drip shield SCC). Although similar arguments can be made to address these agreements, the proposed DOE resolution in this enclosure does not explicitly address these agreements, except for the applicable sections of GEN 1.01 Items 21 and 64. Dispositioning of the remaining agreements will be included in the FY03 and FY04 KTI planning efforts.

CLST 1.12 - Provide the documentation for Alloy 22 and titanium for the path forward items listed on slides 34 and 35 [qualify and optimize mitigation processes; generate SCC data for mitigated material over full range of metallurgical conditions; new vessels for LTCTF will house many of the SCC specimens; continue SSRT in same types of environments as above, specimens in the same range of metallurgical conditions; determine repassivation constants needed for film rupture SCC model to obtain value for the model parameter 'n'; continue reversing direct current potential drop crack propagation rate determinations in same types of environments and same metallurgical conditions as for SSRT and LTCTF tests; evaluate SCC resistance of welded and laser peened material vs non-welded unpeened material; evaluate SCC resistance in induction annealed material; evaluate SCC resistance of full thickness material obtained from the demonstration prototype cylinder of Alloy 22]. DOE will provide the documentation in a revision to AMRs (ANL-EBS-MD-000005 and ANL-EBS-MD-000006) prior to LA.

Enclosure 1
Response to TSPAI Agreement 3.03

GEN 1.01 (9) - Data supporting the residual stress calculations as a result of welding, after laser peening and after induction annealing are not provided. Under existing CLST KTI agreements 1.12 and 2.5, DOE is in the process of generating relevant data for use in a potential LA model for SCC.

GEN 1.01 (10) - The modified stress corrosion cracking parameters are based in recent tests that may not consider the range of possible environments and the effects of fabrication processes. This work is covered under the existing CLST KTI agreements 1.12, 2.5 and 6.1.

GEN 1.01 (21) - DOE will consider the potential for stress corrosion cracking initiation/arrest (KTI agreement TSPAI 3.03), ...

Enclosure 1
Response to TSPAI Agreement 3.03

REFERENCES

BSC 2001a. *Plugging of Stress Corrosion Cracks by Precipitates.* CAL-EBS-MD-000017 REV 00A. Las Vegas, Nevada: Bechtel SAIC Company. Submit to RPC.

BSC 2001b. *Total System Performance Assessment – Analyses for Disposal of Commercial and DOE Waste Inventories at Yucca Mountain – Input to Final Environmental Impact Statement and Site Suitability Evaluation.* SL986M3 REV 00 ICN 02. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20011114.0246

BSC 2001c. *Software Code: GoldSim.* V7.17.200. 10344-7.17.200-00. Las Vegas, Nevada: Bechtel SAIC Company. URN-0901

CRWMS M&O 2000a. *Stress Corrosion Cracking of the Drip Shield, the Waste Package Outer Barrier, and the Stainless Steel Structural Material.* ANL-EBS-MD-000005 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001102.0340.

CRWMS M&O 2000b. *Rock Fall on Drip Shield.* CAL-EDS-ME-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000509.0276.

CRWMS M&O 2000c. *Hydrogen Induced Cracking of Drip Shield.* ANL-EBS-MD-000006 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001025.0100.

CRWMS M&O 2000d. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000007 REV ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045

CRWMS M&O 2000e. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* TDR-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003

CRWMS M&O 2001. *FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation.* ANL-EBS-PA-000002 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL20010216.0004.

Reamer, C. W. and Gil, A. V. 2001. Summary Highlights of NRC/DOE Technical Exchange and Management Meeting on Total System Performance Assessment and Integration and Summary of the Resolution of the Key Technical Issue on Total System Performance Assessment and Integration. ACC: MOL.20010921.0121

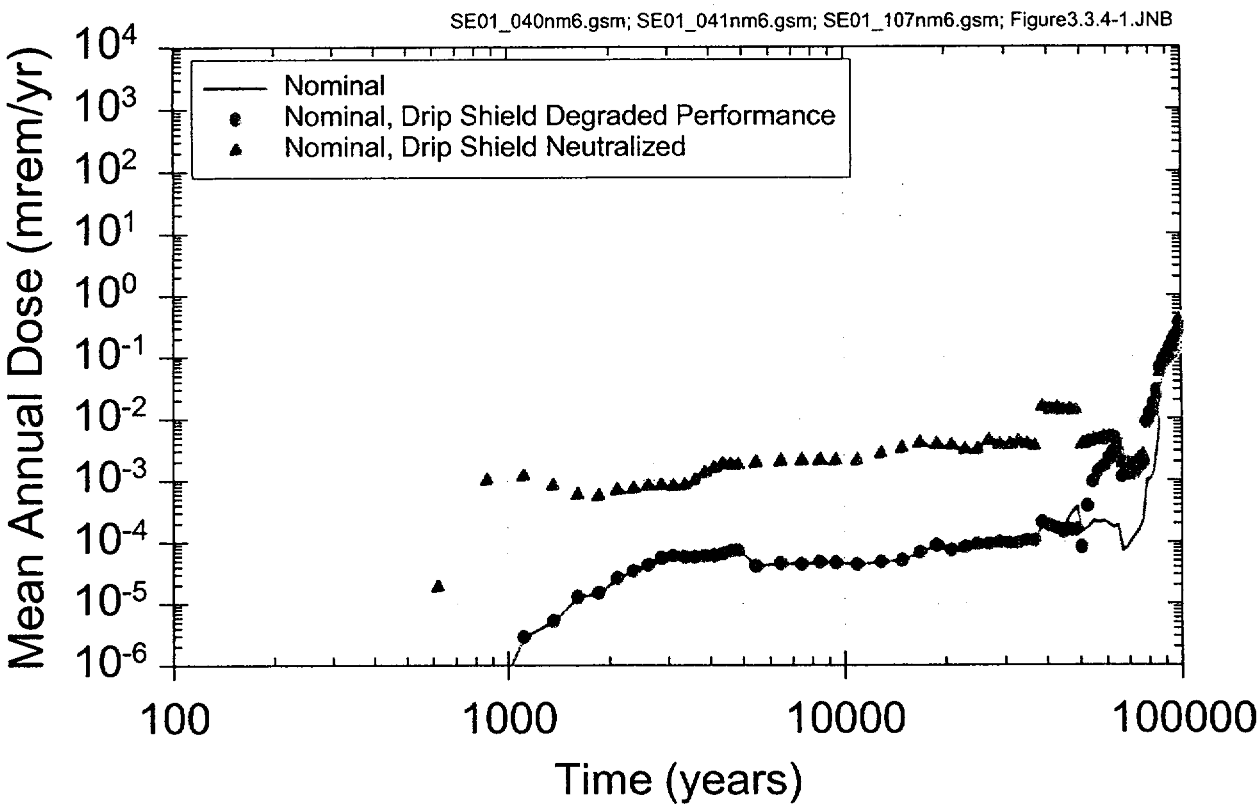

Figure 1. Sensitivity of Mean Annual Dose to the Drip Shield Performance TSPA Model Component[2]

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[2] Each mean annual dose curve for the base case net infiltration model is a probability-weighted average. However, the mean annual dose curves for the sensitivity studies that consider extreme variations to the net infiltration model do not correspond to expected risk because the probability of the variations are not taken into account.