NMSS REVIEW OF THE DOE KTI AGREEMENT RESPONSE TO CLST 1.15 AND GEN 1.01 COMMENT 119 FOR A POTENTIAL GEOLOGIC REPOSITORY AT YUCCA MOUNTAIN, NEVADA

1.0 INTRODUCTION

By letter dated December 9, 2003, the U.S. Department of Energy (DOE) submitted a report, Technical Basis Document No. 6: Waste Package and Drip Shield Corrosion (Bechtel SAIC Company, LLC, 2003a), to satisfy the informational needs of numerous key technical issue agreement items pertaining to the environmental degradation of the waste package and drip shield materials and to respond to issues raised by the U.S. Nuclear Regulatory Commission (NRC) related to corrosion processes and the designs of the waste package and drip shield at the potential repository at Yucca Mountain, Nevada. The information was requested by the NRC staff during previous technical exchanges in September 2000, February 2001, July 2001, August 2001, and September 2001. Specific agreements addressed in this NRC review of the information provided by DOE in the aforementioned technical basis document include CLST 1.15 (Schlueter, 2000) and GEN 1.01 Comment 119 (Reamer, 2001). These agreements were addressed in Appendix D of Technical Basis Document No. 6.

2.0 AGREEMENTS

Wordings of the two agreements are provided next.

CLST 1.15

"Provide the documentation for Alloy 22 and titanium for the path forward items listed on slide 39. [Install specimens cut from welds of SR design mock-up in LTCTF and in other SCC test environments—determine which specimen geometry is most feasible to complement SCC evaluation; evaluate scaling and weld process factors between thin coupons and dimensions in actual welded waste package containers—including thermal/metallurgical structural effects of multi-pass weld processes; provide representative weld test specimens for MIC work, thermal aging and localized corrosion evaluations.] DOE will provide documentation for Alloy 22 and Ti path forward items on slide 39 in a revision to the SCC and general and localized corrosion AMRs (ANL–EBS–MD–000003, ANL–EBS–MD–000004, ANL–EBS–MD–000005) by LA."

GEN 1.01 Comment 119

"In p. 7-9, DOE claimed that NRC accepted the slip dissolution model. The DOE must supply the reference for this acceptance."

3.0 RELEVANCE TO OVERALL PERFORMANCE

Agreement CLST 1.15 is related to the effects of fabrication processes on the susceptibility of the proposed Alloy 22 and titanium materials to stress corrosion cracking, thermal stability, general corrosion, localized corrosion, and microbially influenced corrosion. Agreement GEN 1.01 Comment 119 concerns validation of the slip dissolution model for stress corrosion cracking of Alloy 22 and titanium under relevant repository environments.

The waste package, composed of the containers and the waste forms, is the primary engineered barrier controlling the release of radionuclides from spent nuclear fuel and high-level waste glass. Because corrosion processes, promoted by the presence of an aqueous environment contacting the surface of the containers, will be the primary cause of container failure under undisturbed conditions, the mode and rate of corrosion need to be evaluated to determine container lifetimes. Corrosion processes potentially important in the degradation of the engineered barriers include humid-air and uniform aqueous corrosion, localized (pitting, crevice, and intergranular) corrosion, microbially influenced corrosion, stress corrosion cracking, and hydrogen embrittlement. Fabrication processes, such as cold working, welding, and postweld heat treatments, may alter the corrosion resistance of the waste package materials.

Drip shield performance is an important factor regarding safety because the drip shields are incorporated into the design of the engineered barrier system limit the amount of water contacting the waste package from dripping and preventing rockfall damage. Initiation of aqueous corrosion of the waste packages depends on the deliquescence of dust or the contact with seepage water. Presence of the drip shields will delay contact of seepage water with the waste package surface, resulting in a significantly longer container lifetime. In addition, once the containers are breached, the amount of water available for the dissolution of spent nuclear fuel and high-level waste glass and advective transport of the released radionuclides would be limited, even by the presence of a partially damaged drip shield.

NRC performed a risk insights analysis, which indicated the waste package failure mode to be of medium significance to waste isolation (NRC, 2004). Fabrication processes may alter the mechanical properties, the passive film stability, and the localized corrosion and stress corrosion cracking resistance of the Alloy 22 outer container, which could lead to early through-wall penetration or fracture of the waste package. Microbial activity on or near the waste packages may also alter the local environment and influence waste package corrosion, especially localized corrosion. Stress corrosion cracking of the waste package closure welds has a medium significance to waste isolation. Stress corrosion cracks that penetrate through the waste package outer containers could allow water to contact the waste forms and release radionuclides; however, the transport of water and the release rate of the radionuclides may be restricted by the small apertures of the cracks. The integrity of the drip shield also has a medium significance to waste isolation because while intact, the drip shield will limit the quantity of water contacting the waste packages and waste forms and also limit the formation of aggressive environments on the waste package surfaces.

4.0 RESULTS OF THE NRC REVIEW

Agreements CLST 1.15 and GEN 1.01 Comment 119 are included in the integrated subissue for degradation of engineered barriers. These agreements resulted from a staff review of the DOE documentation that is consistent with NRC (2003, Section 2.2.1.3.1.2, Review Method 2). The NRC review of the response for these agreements also was conducted in accordance with the aforementioned review method. This review method includes evaluation of the sufficiency of the experimental data used to support parameters in conceptual models and process-level models.

4.1 CLST 1.15

The focus of CLST 1.15 was to ensure the assessment of stress corrosion cracking, microbially influenced corrosion, and localized corrosion as potential degradation modes for the waste packages and the drip shield considered the effects of fabrication processes. The DOE response in Appendix D (Bechtel SAIC Company, LLC, 2003a) indicates that Alloy 22 is highly resistant but not immune to stress corrosion cracking in potentially relevant repository environments, based on a broad array of stress corrosion cracking test results. Samples that represent the full range of potential waste package metallurgical conditions have been evaluated for stress corrosion cracking performance. In addition to stress corrosion cracking, there has been no credible evidence that shows significant increase in the general corrosion rate and the susceptibility of Alloy 22 to localized corrosion and microbially influenced corrosion because of long-term thermal aging and fabrication processes.

DOE indicated the possibility of stress corrosion cracking initiation resulting from weld residual stresses can be eliminated for the Titanium Grade 7 drip shield since the drip shield will be emplaced in a stress mitigated condition (Bechtel SAIC Company, LLC, 2001). Titanium Grade 7 is not susceptible to thermal-aging-type accelerated corrosion or mechanical property degradation as a result of phase instability at the maximum expected drip shield exposure temperature of less than 200 EC [392 EF] (Bechtel SAIC Company, LLC, 2003b). Titanium Grade 24 also should remain microstructurally stable. In addition, Titanium Grade 7 is highly resistant to localized corrosion and microbially influenced corrosion in a broad range of potential in-drift concentrated brine environments. Based on results of the range of metallurgical conditions for the waste package and drip shield analyzed for the current level of design and the expected in-drift water chemistry, the DOE response sufficiently addresses the concern associated with Agreement CLST 1.15.

Although the staff considers this agreement closed, DOE should consider the following comments:

C Although the DOE model for stress corrosion cracking of the Alloy 22 waste package outer container is considered conservative, Andresen, et al. (2004) showed that the crack growth rate measured on an Alloy 22 specimen aged at 700 EC [1,292 EF] for 175 hours is near the upper bound of the model. This aging condition, however, is considered to be ultra-severe relative to the expected waste package closure weld thermal exposure (Bechtel SAIC Company, LLC, 2003c). A range of similar microstructures may be expected to result from the fabrication and closure of waste packages, especially elevated temperature exposures during the welding and solution annealing processes. Residual stresses because of fabrication processes also can promote stress corrosion cracking. The models for stress corrosion cracking of the Alloy 22 waste package outer container and the titanium alloy drip shield should be supported by confirmatory tests. These confirmatory tests should evaluate the complete range of alloy compositions, metallurgical conditions, fabrication processes, and postweld stress mitigation methods used in the construction of the waste package and the drip shield. In addition, stress corrosion cracking testing for Alloy 22 samples from mockup containers may be necessary to support the conclusions presented in the technical basis document.

- The conclusion of no increased susceptibility of Alloy 22 to localized corrosion because of fabrication processes was based on the descaled weight-loss results and the polarization resistance corrosion rate measurements (Bechtel SAIC Company, LLC, 2003b). It should be noted that both the weight-loss and polarization resistance methods are for average corrosion rate over a large surface, and may not be sensitive enough for localized corrosion resistance measurements of samples with a fraction of welded region. According to test results reported by Dunn, et al. (2003) and Rebak, et al. (2002), fabrication processes were found to increase the localized corrosion susceptibility of Alloy 22. The possible detrimental effects of fabrication processes on the localized corrosion performance of the waste packages should be carefully evaluated to assure the complete range of potential waste package metallurgical conditions has been considered.

- The DOE response also stated the effect of microbially influenced corrosion of Alloy 22, for both the mill-annealed and as-welded conditions, is currently being investigated. It is not known, however, what methods are being used in the study. Because microbially influenced corrosion is usually manifested in the form of localized corrosion rather than uniform corrosion (Lewandowski, 2000; Little, et al., 2000), the method selected should be suitable for localized corrosion. Yang, et al. (2004) reported the repassivation potential method may not be adequate to determine the microbial effect on the susceptibility of Alloy 22 to localized corrosion because of interference from the reducing species produced by microbial activities. In addition, the DOE 5-year test results for Alloy 22 specimens, exposed in a simulated Yucca Mountain water inoculated with Yucca Mountain rocks, showed uniformly distributed arrays of micropitting. This type of corrosion attack is different from the corrosion observed in the microbial-free environments.

Based on the NRC review of the DOE response to Agreement CLST 1.15 in accordance with methods discussed in the appropriate section of NRC (2003, Section 2.2.1.3.1.2, Review Method 2), NRC found the DOE responses to the agreements to be satisfactory.

4.2 GEN.1.01 Comment 119

DOE responded to Agreement GEN 1.01 Comment 119, which focused on the acceptance of the slip dissolution model, in Appendix D of Bechtel SAIC Company, LLC (2003a). The work of Carpenter and Lund (1999) was cited as the basis for the NRC acceptance of the slip dissolution (GE PLEDGE) model. DOE also recognizes that the model used for stainless steels needs to be validated for Alloy 22 and titanium for the relevant repository environmental conditions. Although NRC has not officially accepted the slip dissolution model, and the stress corrosion cracking model has not been validated for the waste package and drip shield applications, the DOE model abstractions for stress corrosion cracking of the Alloy 22 waste package outer container and the titanium alloy drip shield are conservative (Bechtel SAIC Company, LLC, 2003c). The DOE response sufficiently addresses the concern associated with Agreement GEN 1.01 Comment 119.

Based on the NRC review of the DOE response to Agreement GEN.1.01 Comment 119 in accordance with methods discussed in the appropriate section of NRC (2003, Section 2.2.1.3.1.2, Review Method 2), NRC found the DOE responses to the agreements to be satisfactory.

5.0 SUMMARY

NRC reviewed the DOE key technical issue agreement responses within the report to determine whether any important aspect of Agreements CLST.1.15 and GEN.1.01 Comment 119 was excluded from the response. In addition, NRC performed an independent assessment to determine whether the information provided would support submission of a potential license application for a geologic repository. Notwithstanding new information that could raise new questions or comments concerning these agreements, the information provided satisfies the intent of the agreements. On the basis of this review, NRC agrees with DOE that the information assembled in response to Agreements CLST 1.15 and GEN 1.01 Comment 119 is adequate to support the submission of a license application for the potential repository at Yucca Mountain.

6.0 STATUS OF THE AGREEMENTS

Based on the preceding review, NRC agrees with DOE that the information provided with respect to Agreements CLST 1.15 and GEN 1.01 Comment 119 is adequate to support submission of the license application. Therefore, NRC considers Agreements CLST 1.15 and GEN 1.01 Comment 119 to be closed.

7.0 REFERENCES

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