THE U.S. NUCLEAR REGULATORY COMMISSION OFFICE OF NUCLEAR MATERIAL SAFETY AND SAFEGUARDS REVIEW OF THE U.S. DEPARTMENT OF ENERGY'S KEY TECHNICAL ISSUE AGREEMENT RESPONSES RELATED TO THE POTENTIAL GEOLOGIC REPOSITORY AT YUCCA MOUNTAIN, NV: CONTAINER LIFE AND SOURCE TERM 5.01, 5.03, 5.04, AND 5.05; EVOLUTION OF THE NEAR FIELD ENVIRONMENT 5.01 AND 5.03; RADIONUCLIDE TRANSPORT 4.01 AND 4.03; PRECLOSURE 7.01 AND GENERAL 1.01, COMMENTS 21 AND 64

1.0 INTRODUCTION

By letters dated November 17, 2003 (Ziegler 2003d); February 18, March 12, May 26, August 31, and December 9, 2004 (Ziegler 2004a,b,c,d,e); and January 11, February 7 and 11, 2005 (Ziegler 2005a,b,c), the U. S. Department of Energy (DOE) transmitted information intended to satisfy numerous Key Technical Issue (KTI) agreement items pertaining to pre-closure and post-closure nuclear criticality issues at the potential repository at Yucca Mountain, Nevada. Relevant information (Bechtel SAIC Company, LLC 2004e,f) was also made available on DOE's website in January 2005. The information was requested by the U.S. Nuclear Regulatory Commission (NRC) during previous technical exchanges in October 2000 (Schlueter 2000) and July 2001 (Gil, Reamer 2001). Specific agreements addressed in this NRC review on the information provided by DOE in the referenced transmittals include Container Life and Source Term (CLST) 5.01, 5.03, 5.04, and 5.05; Evolution of the Near Field Environment (ENFE) 5.01 and 5.03; Radionuclide Transport (RT) 4.01 and 4.03; Pre-closure (PRE) 7.01; and General (GEN) 1.01, Comments 21 and 64.

2.0 AGREEMENTS

The wording of the agreements is provided in the subsequent paragraphs.

CLST.5.01

"Provide Revision 1 to the Topical Report. DOE stated that it will provide the Disposal Criticality Analysis Methodology Topical Report, Revision 01, to NRC during January 2001."

CLST.5.03

"DOE will provide an updated technical basis for screening criticality from the post-closure performance assessment. The technical basis will include: (1) a determination of whether the formation of condensed water could allow liquid water to enter the waste package without the failure of the drip shield; and (2) an assessment of improper heat treatment, if it is shown to result in early failure of waste packages, considering potential failure modes. The documentation of the technical basis is comprised of: (1) Analysis of Mechanisms for Early Waste Package Failure AMR; (2) Probability of Criticality Before 10,000 years calculation; and (3) Features, Event, and Process System Level and Criticality AMR. The first document will be provided to NRC in FY02, the second and third documents will be provided in FY03."

CLST.5.04

"Provide the list of validation reports and their schedules. DOE stated that the geochemical model validation reports for "Geochemistry Model Validation Report: Degradation and Release" and "Geochemistry Model Validation Report: Material Accumulation" are expected to be available during 2001. The remainder of the reports are expected to be available during FY2002 subject to the results of detailed planning and scheduling. DOE understands that these reports are required to be provided prior to LA. A list of model validation reports was provided during the technical exchange and is included as an attachment to the meeting summary."

CLST.5.05

"Provide information on how the increase in the radiation fields due to the criticality event affects the consequence evaluation because of increased radiolysis inside the waste package and at the surfaces of nearby waste packages or demonstrate that the current corrosion and dissolution models encompass the range of chemical conditions and corrosion potentials that would result from this increase in radiolysis. DOE stated that the preliminary assessment (calculation) of radiolysis effects from a criticality event will be available to NRC during February 2001. The final assessment of these conditions will be available to NRC prior to LA."

ENFE.5.01

"Provide Revision 1 to the Topical Report. DOE will provide the Disposal Criticality Analysis Methodology Topical Report, Revision 01, to NRC during January 2001."

ENFE.5.03

"Provide the applicable list of validation reports and their schedules for external criticality. DOE stated that the geochemical model validation reports for "Geochemistry Model Validation Report: Degradation and Release" and "Geochemistry Model Validation Report: Material Accumulation" are expected to be available during 2001. The remainder of the reports are expected to be available during FY2002 subject to the results of detailed planning and scheduling. DOE understands that these reports are required to be provided prior to LA. A list of model validation reports was provided during the technical exchange and is included as an attachment to the meeting summary."

RT.4.01

"Provide Revision 1 to the Topical Report. DOE will provide the Disposal Criticality Analysis Methodology Topical Report, Revision 01, to NRC during January 2001."

RT.4.03

"Provide the applicable list of validation reports and their schedules for external criticality. DOE stated that the geochemical model validation reports for "Geochemistry Model Validation Report: Degradation and Release" and "Geochemistry Model Validation Report: Material Accumulation" are expected to be available during 2001. The remainder of the reports are expected to be available during FY2002 subject to the results of detailed planning and

scheduling. DOE understands that these reports are required to be provided prior to LA. A list of model validation reports was provided during the technical exchange and is included as an attachment to the meeting summary."

PRE.7.01

"Provide an update to the Pre-Closure Criticality Analysis Process Report. DOE agreed to provide the report. The report will be available in FY03."

GEN.1.01 Comment 21

The basis for screening criticality from the postclosure performance assessment is contained in a DOE Anaysis Model Report (AMR), "Features, Events, and Processes-System Level and Criticality" that references a document "Probability of Criticality Before 10,000 years." This screening argument relies upon the conclusion that failure of waste packages due to corrosion is not credible during the 10,000 year compliance period. However, analyses in the Supplemental Science and Performance Analyses (SSPA) indicate that early failure of the waste package is credible due to the possibility of improper heat treatment of the closure welds. Therefore, there isn't a sufficient basis to screen criticality from the TSPA calculations. There are not models to evaluate the consequences of a criticality event in the TSPA.

GEN.1.01 Comment 64

Criticality has been screened from the SSPA, without an appropriate technical basis.

Basis:

The DOE screening argument in the System Level and Criticality features, events, and processes AMR was based on the conclusion that no waste packages would fail in the first 10,000 years except as a result of igneous events. The SSPA identifies the possibility of early waste package failure due to improper heat treatment of the closure lid, but does not provide an appropriate screening argument for criticality given this failure.

3.0 RELEVANCE TO OVERALL PERFORMANCE

Agreement PRE.7.01 is associated with the process DOE will use for performing criticality analyses for the Geologic Repository Operations Area. The DOE has indicated that important to safety components that provide moderator controls may be used to prevent preclosure criticality events[1] (Reamer 2004). The DOE also indicated that limiting the amount of fissile material, using geometrically favorable configurations, and using neutron absorbers might

[1] See Slide 6 of "Surface Facility Concept of Operations" presented at the September 14-15, 2004, U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange on The Design of the Surface and Subsurface Facilities at Yucca Mountain, Nevada." (Reamer 2004) ADAMS Accession No. ML042610359.

provide defense-in-depth criticality controls in the fuel handling facility and the aging system[2]. Assumptions used in the criticality analyses may significantly affect the design and the defensibility of arguments concerning criticality safety.

The remaining agreements are associated with the evaluation of postclosure criticality. The DOE intends to design the waste package and engineered barrier system to prevent nuclear criticality events during a 10,000 year period. If successful, criticality events would be excluded from the performance assessment associated with that time period and therefore would have no impact on performance. The DOE may take credit for the engineered barrier system to prevent water from contacting the waste forms and, thus, preventing criticality events. Should water contact the waste form, limited amounts of fissile materials, the use of geometrically favorable configurations, and the use of neutron absorbers in long-lived materials may provide additional means to prevent criticality events. For certain highly enriched waste forms, similar controls may be needed even for dry conditions. The DOE has indicated that criticality control may be an important to waste isolation (ITWI) function of the waste package[3] and the neutron absorber plates may be ITWI[4] (Reamer 2004).

The NRC has performed a risk insights analysis that indicates that postclosure nuclear criticality events have a low significance to waste isolation (NRC 2004). This is based on the expected low probability of criticality events and the anticipated limited effects of criticality events. Failure mechanisms for the waste package and the drip shield, for which DOE may take significant credit in preventing criticality events, have been identified as having high and medium significance to waste isolation. The DOE may also seek approval of neutron absorbing materials, some of which are new or currently under development[5], and may take credit for irradiation of spent fuel (burnup credit)[6] beyond which has been previously approved by the NRC.

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[2] Slides 6 and 14 of "Surface Facilities Design and Operation" presented at the September 14-15, 2004, U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange on The Design of the Surface and Subsurface Facilities at Yucca Mountain, Nevada," identify potential defense-in-depth criticality controls for the Fuel Handling Facility and the Aging System, respectively. (Reamer 2004) ADAMS Accession No. ML042610359.

[3] See Slide 9 of "Surface Facility Waste Handling Operations" presented at the September 14-15, 2004, U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange on The Design of the Surface and Subsurface Facilities at Yucca Mountain, Nevada." (Reamer 2004) ADAMS Accession No. ML042610359.

[4] See Slide 10 of "Surface Facility Waste Handling Operations" presented at the September 14-15, 2004, U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange on The Design of the Surface and Subsurface Facilities at Yucca Mountain, Nevada." (Reamer 2004) ADAMS Accession No. ML042610359. The slides specifically mention absorber plates. These absorber plates are intended to absorb neutrons to reduce the potential for criticality events.

[5] On page 6-41 of (Bechtel SAIC Company, LLC 2004e), DOE indicates that a nickel- gadolinium alloy will be used in the 21-PWR Absorber Plate waste package. Previous transmittals indicated DOE planned to use borated stainless steel as neutron absorbing material. Page 4-16 of the same document indicates that the nickel-gadolinium alloy is specified by ASTM B932-04. Ongoing development work on this material was described at the January 24-28, 2005 American Society of Testing Materials (ASTM) C26.13 Spent Fuel and High Level Waste subcomittee meeting.

[6] Spent Fuel Project Office Interim Staff Guidance 8, rev. 2, "Burnup Credit in the Criticality Safety Analyses of PWR Spent Fuel in Transport and Storage Casks," (Brach 2002) documents a basis for allowing a criticality safety analysis to include inventory changes in actinides during irradiation of fuel. The DOE has proposed for various criticality analyses of waste packages, which are comparable to transport and storage casks, to also take credit for the buildup of fission products.

Finally, prior to the risk insights analysis (NRC 2004), the agreements were previously rated according to risk significance (Travers 2003). This prior analysis identified that nine of the ten agreements addressed in this review were rated as having low significance to risk: CLST.5.01, 5.03, 5.04, and 5.05; ENFE.5.01 and 5.03; RT.4.01 and 4.03; and PRE 7.01 (Travers 2003). While the tenth agreement, GEN 1.01, is considered to be of high-risk significance (Travers 2003), the individual comments within GEN 1.01 (e.g. 21 and 64) were not separately categorized within the significance framework. As GEN 1.01 comments 21 and 64 are associated with CLST 5.03, they may be considered as having low significance to risk.

4.0 RESULTS OF THE NRC REVIEW

Agreements CLST.5.01, 5.03, 5.04, and 5.05; ENFE.5.01 and 5.03; RT.4.01 and 4.03; and GEN.1.01 Comments 21 and 64 are included in the integrated subissue for scenario analysis and event probability. These agreements resulted from a staff review of DOE documentation that is consistent with Review Method 2 in Section 2.2.1.2.2 of the Yucca Mountain Review Plan (NRC 2003). The NRC's review of the response for these agreements also was conducted in accordance with the aforementioned review method. This review method includes the evaluation of the methodology DOE may use to determine the probability of postclosure criticality events.

Agreement PRE.7.01 is associated with the design of structures, systems and components important to safety and safety controls. This agreement resulted from a staff review of DOE documentation that is consistent with Review Method 1 in Section 2.1.1.7.2.1 of the Yucca Mountain Review Plan (NRC 2003). The NRC's review of the response for this agreement also was conducted in accordance with the aforementioned review method. This review method includes an evaluation of whether DOE's preclosure criticality design criteria are consistent with NRC guidance and National Consensus Standards.

Because criticality events are currently ranked as having low significance to waste isolation, NRC staff conducted only high level reviews of DOE's responses to the criticality agreements. The staff's review focused on whether DOE has sufficiently described the methodologies, along with the data and analyses used to justify the methodologies, that would be used to evaluate potential criticality events in a License Application (LA). Staff did not determine whether the methodologies or analyses presented in DOE's responses or supporting documents were technically acceptable.

Staff pre-licensing activities specific to reviewing the adequacy of DOE's responses to the KTI agreements on criticality are complete. However, the staff intends to continue to review DOE information related to criticality for the purpose of preparing for a potential LA. This includes information associated with the criticality screening analysis, the criticality topical report and supporting model reports, and the preclosure criticality reports (discussed in more detail below)[7]. As appropriate, the staff may provide DOE with feedback or request interactions to

[7] Because DOE chose to use a topical report approach (Holonich 1994) to evaluate potential criticality events, the criticality agreements were primarily related to methodological issues. The staff may review a broader range of criticality related information than covered by the criticality related agreements, should such information become available, in preparing to review a potential LA.

facilitate its understanding of DOE's approach to criticality safety.

4.1 CLST.5.01, ENFE.5.01, and RT.4.01

The focus of CLST.5.01, ENFE.5.01, and RT.4.01 was for DOE to provide an update to the Disposal Criticality Analysis Methodology Topical Report (TR). The three agreements cover postclosure criticality events in a waste package, in the near field, and in the far field, respectively. The DOE originally documented its criticality analysis methodology in the TR (DOE 1998). The NRC documented its review of the original TR in a Safety Evaluation Report (SER) (NRC 2000) which identified 28 open items. The above agreements involved DOE committing to provide a revision to the TR which would address the open items. The DOE response (Ziegler 2003d; 2004a,b; 2005a,b) provides revision 2 of the TR (DOE 2003), discussions on how the open items have been addressed, and a request to close the agreements. There have been several other transmittals regarding these agreements besides those specifically addressed in this evaluation that provide some context (Brocoum 2001, Reamer 2001, Ziegler 2003b).

The staff conducted a high level review, as described in section 4.0 above, of the revised TR (DOE 2003) along with the discussions of the open items (Ziegler 2004a; 2005a,b). While the staff is discontinuing the topical report approach (Holonich 1994) for criticality postclosure issues and has no plans to issue a revised SER, the staff finds the revised TR (DOE 2003) generally has the type of information needed to allow a technical review. Therefore the agreements are closed.

4.2 CLST.5.03 and 5.05, GEN.1.01 Comments 21 and 64

The focus of CLST.5.03 is for DOE to provide an updated technical basis for screening postclosure criticality events, addressing specific technical issues such as condensation and waste package failure modes. The focus of GEN.1.01 Comments 21 and 64 is for the screening argument for criticality events to include appropriate consideration of early failures of the waste package and to provide a technical basis for screening criticality events, respectively. The focus of CLST.5.05 is for DOE to evaluate how radiolysis affects the consequences of criticality events. CLST.5.05 is related to CLST.5.03 such that if DOE could provide a defensible screening argument, the consequences of criticality events would no longer need to be evaluated and CLST.5.05 would not be applicable. There have been several other transmittals regarding CLST.5.05 besides those specifically addressed in this evaluation that provide some context (Brocoum 2001b, CRWMS M&O 2001, Schlueter 2002b, Ziegler 2002b, Rom 2003).

The DOE response (Ziegler 2004d) to CLST.5.03 and GEN.1.01 Comments 21 and 64 indicated that reports supporting the agreements, including a comprehensive screening analysis (Bechtel SAIC Company, LLC 2004e) and an analysis of early waste package and drip shield failure mechanisms (Bechtel SAIC Company, LLC 2004f) had been developed and would be made available. These reports, including the screening analysis, were subsequently made available on DOE's website in January 2005. Based on a high level review, staff found that the reports have the type of information needed to allow a technical review. Therefore, CLST.5.03 and GEN.1.01 Comments 21 and 64 are closed.

The DOE response (Ziegler 2004d) to CLST.5.05 indicated that the screening analysis (Bechtel

SAIC Company 2004, LLC 2004e) demonstrates that criticality events will be screened out on the basis of low probability of occurrence. Based on DOE's intention to exclude the consequences of criticality events from the performance assessment and the screening analysis generally having the type of information needed to allow a technical review, CLST.5.05 is closed.

4.3 CLST.5.04, ENFE.5.03, and RT.4.03

The focus of CLST.5.04, ENFE.5.03, and RT.4.03 is for DOE to identify and provide the model validation reports supporting the TR prior to the LA. The three agreements cover criticality events in a waste package, in the near field, and in the far field, respectively.

The DOE response identifies eight model validation reports that provide the technical basis for the methods used in evaluating criticality events (Ziegler 2004d). Reports 1 and 2 discuss the geochemical models DOE will use to determine the potential critical configurations. Report 3 discusses the configuration generator model DOE will use to determine the probability of potential criticality events. Reports 4 and 5 discuss the criticality and isotopic models DOE will use to evaluate the reactivity of potential configurations. Reports 6, 7, and 8 discuss criticality consequence models DOE would use if criticality events are shown to be credible. The DOE shows the correspondence of the current list of model validation reports to previous lists of reports DOE previously committed to providing in Table 1. Various antecedent versions of these reports (Bechtel SAIC Company, LLC 2001a, b; 2003a,b,c) have been provided or discussed by DOE (Brocoum 2001b, Ziegler 2003a, 2003c) and responded to by the NRC (Schlueter 2002b, 2003)

The DOE response (Ziegler 2004d) to CLST.5.04, ENFE.5.03, and RT.4.03 does not sufficiently describe the methodologies, along with the data and analyses used to justify the methodologies, used to determine potential criticality configurations. Specifically:

- The DOE response does not provide the geochemical model reports identified as reports 1 and 2 in DOE's response (Ziegler 2004d) or a schedule for providing the reports. Previously, DOE indicated that a revised geochemical model report with a film degradation model would be provided prior to the submittal of the LA (Ziegler 2003a).

- The DOE has not indicated how it plans to address additional information needs (AINs) associated with the geochemical reports (Schlueter 2002b).

In preparing to review a potential LA, the information above is necessary for the staff to understand the geochemical methodology, along with the data and analyses used to justify the methodology, that DOE will use to determine potential configurations in the waste package. DOE identifies in Assumption 5.1.1 of the screening analysis (Bechtel SAIC Company, LLC 2004e) that 10% of the waste packages may fail due to localized corrosion processes. This may allow oxidizing conditions, along with thin films of water, to develop within waste packages (DOE does not take credit for the waste package inner barrier). Degradation resulting from these conditions may lead to reconfiguration of the waste package contents (basket structure and waste forms). The DOE may identify other conditions that might affect the configuration of waste package contents, such as bulk water or mechanical disruption, as the Total System

Performance Assessment (TSPA) is updated[8]. Alternatively, DOE could provide a rational why the above information is no longer necessary. Since DOE has not provided relevant information on the geochemical models it plans to use to determine potential criticality configurations, the agreements remain open.

The DOE response indicated that configuration generator, criticality, and isotopic model reports (Reports 3, 4, and 5) (Ziegler 2004d) would be made available separately. The DOE subsequently provided these reports to the NRC (Bechtel SAIC Company, LLC 2004a,b,c, 2005c). Based on a high level review, staff found that the reports generally have the type of information needed to conduct a technical review. Therefore this portion of the response is satisfactory.

The DOE response concerning the criticality consequences related reports (Report 6, 7, and 8) (Ziegler 2004d) indicated that these reports will not be submitted prior to a potential LA since DOE is screening out criticality events. Based on DOE's intention to exclude the consequences of criticality events from the performance assessment, and the screening analysis generally having the type of information needed to allow a technical review, this portion of the response is satisfactory.

In summary, the responses with regard to the configuration generator, criticality, isotopic, and consequence model reports are satisfactory. However, relevant information on the geochemical models was not provided. Therefore, the agreements remain open.

4.4 PRE.7.01

The focus of PRE.7.01 is for DOE to describe its process for performing the preclosure criticality analysis. In response to PRE.7.01, DOE provided (Ziegler 2004c) a report describing the methods it may use to evaluate potential preclosure criticality events (Bechtel SAIC Company, LLC 2004e). The staff conducted a high level review of the report as described in section 4.0 above. The report generally contains the type of information needed to allow a technical review. Therefore, the agreement is closed.

5.0 SUMMARY

The NRC conducted high level reviews of DOE's KTI agreement responses and associated documents made available by DOE to determine whether sufficient information was available to allow a technical review of the issues associated with Agreements CLST.5.01, 5.03, 5.04, and 5.05; ENFE.5.01 and 5.03; RT.4.01 and 4.03; PRE.7.01 and GEN.1.01 Comments 21 and 64. On the basis of these reviews, NRC agrees with DOE that the information assembled (agreement responses and associated documents) in response to Agreements CLST.5.01, 5,03, and 5.05; ENFE.1.01; RT.5.01; PRE.7.01; and GEN.1.01 Comments 21 and 64 is adequate to support the submission of the LA for the potential repository at Yucca Mountain.

[8] The DOE identifies several assumptions in the criticality screening analysis (Bechtel SAIC Company, LLC 2004e) that require confirmation with the completion and verification of the TSPA (or supporting analyses) for the LA. These assumptions affect the conditions postulated to occur inside the waste package.

NRC considers Agreements CLST.5.04, ENFE.5.03, and RT.4.03 open. Information that the NRC would find useful in preparing for the review of a potential LA associated with these agreements includes: (1) the geochemical reports identified in DOE's response; and (2) DOE plans to address the AINs associated with the geochemical reports.

Staff pre-licensing activities specific to reviewing the adequacy of DOE's responses to the KTI agreements on criticality are complete. However, the staff intends to continue to review DOE information related to criticality for the purpose of preparing for a potential LA. This includes information associated with the criticality screening analysis, the criticality topical report and supporting model reports, and preclosure criticality reports. As appropriate, the staff may provide DOE with feedback or request interactions to facilitate its understanding of DOE's approach to criticality safety.

6.0 STATUS OF THE AGREEMENTS

Based on the above review, NRC staff agrees with DOE that the information provided with respect to Agreements CLST.5.01, 5.03, and 5.05; ENFE.5.01; RT.4.01; PRE.7.01; and GEN.1.01 Comments 21 and 64, along with documents made available on DOE's website, is adequate to support the submission of the LA. Therefore, NRC considers Agreements CLST.5.01, 5.03, and 5.05; ENFE.5.01; RT.4.01; PRE.7.01; and GEN.1.01 Comments 21 and 64 to be closed.

Base on the above review, NRC staff concluded that the information provided by DOE with respect to Agreements CLST.5.04, ENFE.5.03, and RT.4.03 does not satisfy the intent of the agreements. The previous status of CLST.5.04, ENFE.5.03, and RT.4.03 was open (previously referred to as partly received) and the NRC considers that these agreements remain open.

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