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, NEVADA: IGNEOUS ACTIVITY 2.03 ADDITIONAL INFORMATION NEEDED; 2.09 ADDITIONAL INFORMATION NEEDED; 2.19; AND 2.20

1.0 INTRODUCTION

The U.S. Nuclear Regulatory Commission (NRC) issue resolution goal during the prelicensing period is to ensure the U.S. Department of Energy (DOE) has assembled enough information about a given issue for NRC to accept a License Application for review. Resolution by the NRC staff during prelicensing does not prevent anyone from raising any issue for NRC consideration during the licensing proceedings. Also, and just as important, resolution of an issue by NRC during prelicensing does not prejudge the NRC staff evaluation of the issue during the licensing review. Issues are resolved by NRC's staff during prelicensing 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 about a previously resolved issue.

This review addresses additional information supplied by DOE to support Igneous Activity (IA) Key Technical Issue (KTI) Agreements IA.2.03 and 2.09, which were originally made between DOE and NRC during the IA Technical Exchange and Management Meeting (Schlueter, 2000). Additionally, this review evaluates information supplied by DOE to support KTI Agreements IA.2.19 and 2.20, which were made between DOE and NRC during the IA Technical Exchange and Management Meeting (Reamer, 2001a). These four agreements affect models for the potential release and transport of radionuclides during potential igneous events. In Travers (2003), staff described the basis for risk-ranking the KTI agreements. Agreements that affected risk calculations through moderate increases in radionuclide transport characteristics were considered to have medium significance in performance calculations. The NRC preliminary analyses indicate these four agreements have a medium significance to risk calculations (Travers, 2003).

2.0 WORDINGS OF THE AGREEMENTS

Agreement IA.2.03 is defined in an NRC staff letter (Schlueter, 2000), which summarizes the IA Technical Exchange and Management Meeting held August 29–31, 2000. The wording of the agreement is as follows:

IA.2.03

"Document how the tephra volumes from analog volcanos represent the likely range of tephra volumes from Yucca Mountain Region (YMR) volcanoes. (Eruptive AC–1) DOE agreed and will document the basis for determining the range of tephra volumes that is likely from possible future volcanoes in the YMR in the Eruptive Processes AMR (ANL–MGR–GS–000002). This will be available to the NRC in FY2002."

The DOE previously responded to Agreement IA.2.03 (Ziegler, 2002a). After reviewing this response, NRC identified an additional information need (AIN-1), referred to as IA.2.03 AIN-1 (Schlueter, 2002). The wording of IA.2.03 AIN-1 follows.

<u>IA.2.03 AIN-1</u>

“DOE needs to: (a) Provide a technical basis for demonstrating how tephra volumes have been calculated based on eroded deposits in the YMR, (b) Provide a technical basis for the inclusion of analog information, and (c) Demonstrate how buried deposits, such as the flows from Little Cones, has been incorporated into the calculation of tephra volumes. In addition, the apparent lack of sensitivity of tephra volume in performance assessment calculations should be demonstrated under appropriate wind conditions.”

Agreement IA.2.09 is defined in an NRC staff letter (Schlueter, 2000), which summarizes the IA Technical Exchange and Management Meeting held August 29–31, 2000. This agreement was modified during the IA Technical Exchange and Management Meeting held June 21–22, 2001 (Reamer, 2001b). The wording of the modified agreement is as follows:

<u>IA.2.09</u>

“Use the appropriate wind speeds for the various heights of eruption columns being modeled. DOE agreed and will evaluate the wind speed data appropriate for the height of the eruptive columns being modeled. This will be documented in a calculation document. This will be available to the NRC in FY 2002.”

DOE previously responded to Agreement IA.2.09 (Ziegler, 2002b). After reviewing this response, NRC identified an AIN-1, referred to as IA.2.09 AIN-1 (Schlueter, 2003). The wording of IA.2.09 AIN-1 follows.

<u>IA.2.09 AIN-1</u>

“The DOE needs to demonstrate that the wind speed used in performance assessment is appropriate for the height of the eruption column. The DOE should demonstrate that neglecting the effects of higher velocity winds expressed during particle rise and lateral advection does not underestimate risk. If the DOE chooses to convolve wind-speed data into a single distribution for use in performance assessment, the DOE should document how appropriate weight was given in the distribution to upper altitude winds representative of lateral advection processes typically observed in volcanic eruption plumes. The DOE wind speed parameter distribution also should reflect the characteristics of the parameter distribution used for eruption column height, to avoid potential bias towards lower altitude wind speeds. As this information will be used in the TSPA-LA, the DOE needs to provide this information in a format that meets the requirements of the DOE quality assurance program.”

Agreement IA.2.19 is defined in an NRC staff letter (Reamer, 2001a), which summarizes the IA Technical Exchange and Management Meeting held September 5, 2001. The wording of the agreement is as follows:

<u>IA.2.19</u>

“DOE will evaluate waste package response to stresses from thermal and mechanical effects associated with exposure to basaltic magma, considering the results of evaluations attendant to IA Agreement 2.18. As currently planned, the evaluation, if implemented, would include (1) appropriate at-condition strength properties and magma flow paths, for duration of an igneous event; and (2) aging effects on materials strength properties when exposed to basaltic magmatic conditions for the duration of an igneous event, which will include the potential effects of subsequent seismically induced stresses on substantially intact waste packages. DOE will also evaluate the response of Zone 3 waste packages, or waste packages covered by backfill or rockfall, if exposed to magmatic gasses at conditions appropriate for an igneous event, considering the results of evaluation attendant to IA Agreement 2.18. If models take credit for engineered barriers providing delay in radionuclide release, DOE will evaluate barrier performance for the duration of the hypothetical igneous event. The results of this investigation would be documented in an update to the technical product *Waste Package Behavior in Magma* CAL–EBS–ME–000002, which would be available by the end of FY 2003, or other appropriate technical document.”

Agreement IA.2.20 is defined in an NRC staff letter (Reamer, 2001a), which summarizes the IA Technical Exchange and Management Meeting held September 5, 2001. The wording of the agreement is as follows:

<u>IA.2.20</u>

“DOE will evaluate how ascent and flow of basaltic magma through repository structures could result in processes that might incorporate HLW, considering the results of evaluations attendant to IA Agreements 2.18 and 2.19. As currently planned, the evaluation, if implemented, would include the potential for HLW incorporation along reasonable potential flow paths that could develop during an igneous event. The evaluation would also include the physical and chemical response of HLW and cladding after heating and potential disruption of waste package and contents, for waste packages remaining in drifts. The evaluation would examine effects that may result in increased solubility potential relative to undisturbed HLW forms. The results of this investigation would be documented in a new AMR to document the waste form response to magmatic conditions, which is expected to be available by the end of FY 2003. DOE will describe the method of HLW incorporation used in DOE models, including consideration of particle aggregation and the effect on waste transport. If models take credit for engineered barriers providing delay in radionuclide release, DOE will evaluate barrier performance for the duration of the hypothetical igneous event. This will be documented in an update to the igneous consequences AMR, ANL–WIS–MD–000017, which is expected to be available in FY 2003, or another appropriate technical document.”

3.0 SIGNIFICANCE OF ISSUES TO PERFORMANCE

Agreement IA.2.03 AIN-1 requests DOE to provide additional support for the calculation of tephra volumes used in models of potential volcanic events in the Yucca Mountain region. The volume of tephra affects models used to simulate the airborne transport of radionuclides during potential volcanic eruptions. Tephra volume also affects the calculated concentration of high-level waste in potential volcanic deposits, because of simple dilution effects associated with larger tephra volumes. However, nearly all the original tephra deposits have been eroded from the exposed basaltic volcanoes in the Yucca Mountain region. Thus, tephra deposit volumes cannot be measured directly at Yucca Mountain region volcanoes, and alternative methods must be used to evaluate a range of potential volumes for future igneous events. Based on available risk insights (Travers, 2003; Mohanty, et al., 2004; NRC, 2004), staff determined that tephra volumes have medium significance to performance calculations.

Agreement IA.2.09 AIN-1 requests DOE to provide additional support for the use of selected wind characteristics to represent atmospheric conditions at appropriate altitudes for modeled volcanic eruption columns. This information has a direct impact on models for the dispersal of tephra from potential volcanic events (e.g., sensitive to assumptions for wind speed and direction). Higher wind velocities can advect airborne tephra particles further downwind in the eruption plume than occurs for relatively lower wind velocities. Eruption plumes also can be directed away from the location of the reasonably maximally exposed individual, depending on wind direction and velocity. Based on available risk insights (Travers, 2003; Mohanty, et al., 2004; NRC, 2004), staff determined that wind characteristics have medium significance to performance calculations.

Agreement IA.2.19 requests DOE to provide additional support for models of waste package response to conditions associated with basaltic intrusive events. This information impacts the number and extent of damage to waste packages and its input to source-term determination for radionuclide release calculations. Multiple drifts could be intersected by a potential intrusive igneous event. Thus, a large increase in radionuclide source-term could occur if many or all of the waste packages in intersected drifts were extensively damaged during potential intrusive igneous events. Based on available risk insights (Travers, 2003; Mohanty, et al., 2004; NRC, 2004), staff determined that waste package response to conditions during intrusive igneous events has a medium significance to performance calculations.

Agreement IA.2.20 requests DOE to provide additional information regarding the response of the wasteform to the physical conditions of a potential igneous event. This information is important because the thermal, mechanical, and/or chemical conditions of a potential igneous event could affect the characteristics of the wasteform and increase radionuclide release rates during subsequent hydrologic flow and transport. Based on available risk insights (Travers, 2003; Mohanty, et al., 2004; NRC, 2004), staff determined that waste form response to conditions during intrusive igneous events has a medium significance to performance calculations.

4.0 EVALUATION AND COMMENT

The combined DOE response to Agreements IA.2.03 AIN-1; 2.09 AIN-1; 2.19; and 2.20 is provided in Appendixes A–D of Bechtel SAIC Company, LLC (2003a). These four IA KTI agreements are relevant to understanding important aspects of IA Subissue 2, Consequences of IA, and have been reviewed by staff in that context. Staff evaluated the information provided by DOE using review methods for the Volcanic Disruption of Waste Packages, Airborne Transport of Radionuclides, and Mechanical Disruption of Engineered Barriers sections in the Yucca Mountain Review Plan (NRC, 2003).

4.1 Agreement IA.2.03 AIN-1

In Appendix A of Bechtel SAIC Company, LLC (2003a), DOE summarizes additional information that clarifies the method used to estimate tephra volumes from past eruptions in the Yucca Mountain region. The DOE focuses on the youngest volcano in the Yucca Mountain region, Lathrop Wells volcano, because tephra deposits from this volcano are the best preserved in this region. By using standard volume estimation techniques, DOE concludes the volume of Lathrop Wells tephra deposits was approximately 0.04 km^3 [0.01 mi^3]. This tephra volume is twice the volume of the associated scoria cone, which is an average volume relationship observed at other historical basaltic scoria-cone eruptions (NRC, 1999; Bechtel SAIC Company, LLC, 2003a). Variability in the potential tephra volume for future eruptions is estimated by DOE at the upper limits by increasing the Lathrop Wells tephra volume by a factor of two {i.e., 0.08 km^3 [0.02 mi^3]}, with a lower limit of 0.004 km^3 [0.001 mi^3] defined by the Little Cones volcano in Crater Flat (Bechtel SAIC Company, LLC, 2003a).

The information provided in Bechtel SAIC Company, LLC (2003a) clearly explains the methods used by DOE to estimate tephra volumes for Quaternary volcanic eruptions in the Yucca Mountain region. Tephra volumes are estimated based on scaling relationships to cone volumes and are derived independently from lava flow volumes. The DOE also provides a short explanation for the use of selected analog volcanoes to constrain volume relationships between scoria cones and tephra deposits (Bechtel SAIC Company, LLC, 2003a). This information was not available in previous DOE reports (e.g., CRWMS M&O, 2000a). In addition, the current DOE modeling approach for airborne transport of tephra no longer uses eruption volume to constrain column height.

Although cone and tephra deposits are best preserved at Quaternary volcanoes in the Yucca Mountain region, the limited number of Quaternary volcanoes does not fully represent an appropriate range of possible tephra volumes for future eruptions. Available information suggests larger tephra volumes than currently used by DOE may be more representative of older eruptions in the Yucca Mountain region. For example, Bechtel SAIC Company, LLC (2003a) suggests the volume of deposits for the buried 3.8 million-year-old volcano associated with Aeromagnetic Anomaly B may be greater than any single Quaternary deposit. The eroded remnants of Pliocene scoria cones in Crater Flat also indicate larger tephra volumes than accounted for in the current DOE parameter range (Bechtel SAIC Company, LLC, 2003b). In addition, most DOE probability models for future igneous events consider volcanoes up to 5 million years old as relevant to the recurrence rate estimates (e.g., Bechtel SAIC Company, LLC, 2003b). Thus, not including volcanic events up to 5 million years old from the range of estimated tephra volumes for future volcanic events appears inconsistent with the DOE basis used to estimate the likelihood of future volcanic events in the Yucca Mountain region.

The DOE performance calculations use tephra volume as a simple input parameter in the airborne transport model for volcanic events. The technical basis used by DOE to develop a preferred tephra-volume range represents a traceable methodology, although alternative interpretations to available data can be derived. Independent staff analyses can be used to evaluate the risk significance of alternative interpretations of tephra volumes in performance calculations (e.g., NRC, 2004). Although some differences appear to exist between DOE and NRC estimates of tephra volumes for past Yucca Mountain region volcanic events (cf., NRC, 1999), the magnitude of the current differences does not appear to affect performance calculations significantly (NRC, 2004). Nevertheless, DOE could strengthen its technical basis by providing a transparent linkage between the tephra volumes used in the performance calculations and the tephra volumes likely associated with the range of volcanic events used to derive the DOE probability estimate. Based on currently available information, staff concludes that DOE has acceptably addressed the specific questions raised in Agreement IA.2.03 AIN-1.

4.2 Agreement IA.2.09 AIN-1

In Appendix B of Bechtel SAIC Company, LLC (2003a), DOE clarifies the method used to represent wind speed and direction in performance calculations of potential volcanic events at Yucca Mountain. The current DOE modeling approach for atmospheric dispersal of volcanic tephra (Bechtel SAIC Company, LLC, 2004a) differs significantly from previous DOE models (e.g., CRWMS M&O, 2000b). Previously, DOE's models did not provide a clear linkage between the wind characteristics used in the dispersal calculations and the height of the eruption column. However, the current DOE model now assumes that wind speed and wind direction characteristics of the altitude at the top of the eruption plume represent atmospheric conditions for tephra dispersal calculations. The DOE uses wind characteristics from radiosonde data collected in 1978–1993 at the Desert Rock airstrip, Nevada (Bechtel SAIC Company, LLC, 2004a). These wind data are binned into 1-km [0.6-mi]-high intervals and distributions of wind speed and direction are produced for each interval. The DOE tephra dispersal model independently calculates the altitude of the top of the eruption column, then samples wind speed and direction distributions from the 1-km [0.6-mi]-high interval corresponding to the top of the eruption column (Bechtel SAIC Company, LLC, 2004a).

The information provided in Appendix B of Bechtel SAIC Company, LLC (2003a) to address Agreement IA.2.09 AIN-1 appears sufficient for staff review of DOE's modeling approach for atmospheric dispersal of volcanic tephra. The DOE has provided a traceable basis to relate wind characteristics used in the dispersal modeling to eruption characteristics used in the same model. However, staff notes the wind data from Desert Rock airstrip reported in Attachment III of Bechtel SAIC Company, LLC (2004a) may contain additional errors. Staff analysis of the 1978–1997 Desert Rock data, which were independently acquired from the U.S. National Oceanographic and Atmospheric Agency, results in an approximately twofold increase in average wind speed relative to the reportedly identical data used in Bechtel SAIC Company, LLC (2004a). In addition, this data set does not contain the numerous errors in the 1994–1995 observations reported in Attachment III of Bechtel SAIC Company, LLC (2004a). Although staff is aware of ongoing DOE investigations to reconcile these differences in the Desert Rock wind data, results of these investigations are not yet available. Reconciliation of these differences in wind data appears important to support DOE's performance calculations. If such differences exist during license review, the staff could evaluate the likely risk significance of potential differences using alternative parameter distributions for wind speed and wind direction. Based on currently available information, staff concludes that DOE has acceptably addressed the specific questions raised in Agreement IA.2.09 AIN-1.

4.3 Agreement IA.2.19

In Appendix C of Bechtel SAIC Company, LLC (2003a), DOE presents a significantly revised conceptual model for waste package response to conditions occurring in drifts affected by a potential igneous intrusive event. Previously, DOE assumed significant damage occurred to only the first three waste packages located on either side of an igneous intrusion that intersected a drift (CRWMS M&O, 2000c). Other waste packages in potentially intersected drifts were modeled by DOE as having only small end-cap failures. Waste packages located in adjacent, nonintersected drifts did not experience any adverse effects from potential igneous events. However, the limited information available about waste package response to potential igneous conditions; did not appear to support many of the assumptions in CRWMS M&O (2000c,d) for waste package resiliency during potential igneous intrusive events (e.g., NRC, 1999, 2002).

The current DOE model for waste package response to potential igneous conditions concludes the combined thermal, mechanical, and chemical effects of direct contact by basaltic magma will remove the waste isolation functions of waste packages (Bechtel SAIC Company, LLC, 2003a, 2004b). The DOE also assumes there will be no naturally occurring rockfall or engineered backfill to possibly mitigate these effects in potentially intersected drifts (Bechtel SAIC Company, LLC, 2003a). Thus, performance calculations assume the waste isolation functions are removed from all waste packages in drifts potentially intersected by basaltic magma (Bechtel SAIC Company, LLC, 2003a). This assumption appears reasonable given currently available information (NRC, 1999, 2002; Bechtel SAIC Company, LLC, 2004b). Although DOE continues to evaluate alternative interpretations for waste package response to basaltic magma (Bechtel SAIC Company, LLC, 2003a), propagation of this assumption through performance calculations addresses staff questions in Agreement IA.2.19 regarding at-condition strength properties and aging effects on waste package performance during igneous intrusive events.

The DOE has conducted additional analyses to evaluate the possible thermal and chemical effects on waste packages in drifts located adjacent to drifts potentially intersected by basaltic magma. These analyses are needed because basaltic magmas can produce gases that could measurably increase the corrosion rates of steel and other metal alloys (Bechtel SAIC Company, LLC, 2003a). The DOE uses an advective-diffusive process model to evaluate the potential migration of magmatic gases from a drift intersected by magma to an adjacent, nonintersected drift (Bechtel SAIC Company, LLC, 2004b). This generalized advection model relies on a critical assumption regarding the extremely low effective permeability of the potentially intruded basalt. Although Bechtel SAIC Company, LLC (2004b) cites permeability information from analog basaltic intrusions to support this assumption, the uncertainties in these data do not consider the potential effects on basalt permeability arising from interactions between flowing magma and engineered systems in a 5-m [16-ft]-diameter drift.

Joints and fractures develop in cooling magmas in response to the cooling rate and the orientation to cooling surfaces (e.g., DeGraff and Aydin, 1993). Potential repository drifts containing waste packages, supports, and drip shields present multiple cooling surfaces for possible basaltic magmas, relative to the simple cooling geometries in analog intrusions. The DOE analog intrusion sites such as Paiute Ridge, Nevada, also represent much larger volumes of magma than could potentially fill a drift (Bechtel SAIC Company, LLC, 2003c). Although a magma-filled drift is modeled by DOE as cooling to ambient temperatures within approximately

30 years (Bechtel SAIC Company, LLC, 2004b), the Paiute Ridge intrusion likely remained hundreds of degrees above ambient temperatures for at least 200–300 years following intrusion (Ratcliff, et al., 1994). These significant differences in cooling rate and surface orientations could result in significant differences in fracture abundances between analog intrusion sites and potential magma emplaced in drifts. Based on these effects, the permeability of cooled magma in a drift could be similar to host rock permeabilities {i.e., on order of 10^{-12} m^2 [10^{-11} ft^2], Rosseau, et al., 1999} rather than on order of 10^{-17} m^2 [10^{-16} ft^2] as used in the DOE models (Bechtel SAIC Company, LLC, 2003c). Thus, current DOE models may underestimate the amount and composition of corrosive magmatic gases that could advect from drifts potentially intersected by basaltic magma into adjacent, nonintersected drifts. This effect may lead to larger uncertainties in the radiological source term used by DOE to evaluate the significance of igneous intrusive events in performance calculations (Bechtel SAIC Company, LLC, 2003a).

The DOE has conducted additional analysis to acceptably address and support conclusions regarding waste package response to direct contact by basaltic magma (i.e., Zone 1 in Bechtel SAIC Company , LLC, 2004b). However, it does not appear that DOE has considered a realistic range of rock permeabilities in models for advective gas flow between potentially intersected drifts (Zone 1) and adjacent, nonintersected drifts (i.e., Zone 2 in Bechtel SAIC Company , LLC, 2004b). Because exposure to magmatic gases could accelerate metal corrosion rates, and increase radiological source-terms in Zone 2 for an igneous intrusive event, the NRC considers the DOE response to Agreement IA.2.19 to be insufficient to close this agreement at this time.

In any potential license application, DOE should provide analysis which considers a realistic range in rock permeabilities in evaluating gas flow and its affect on canister performance in Zone 2 or demonstrates that the accelerated degradation on canister performance in Zone 2 is not significant.

4.4 Agreement IA.2.20

In Appendix D of Bechtel SAIC Company, LLC (2003a), DOE provides additional information regarding the wasteform response to basaltic igneous conditions. For waste packages located in drifts not intersected by basaltic magma, DOE's models conclude there will be no adverse thermal or chemical effects from nearby basaltic magmatism that would adversely affect waste package performance (Bechtel SAIC Company, LLC, 2004b). Thus, the waste form in these unaffected drifts also would not be affected by potential IA in adjacent drifts. Staff concerns with the current DOE analyses for gas flow into nonintersected drifts are discussed in Section 4.3 of this report.

Current DOE models conclude that waste packages located in drifts potentially intersected by basaltic magma will lose their waste isolation functions because the adverse physical, thermal, and chemical conditions during this event (Bechtel SAIC Company, LLC, 2004b). This information also indicates that cladding will fail during a potential basaltic igneous event (Bechtel SAIC Company, LLC, 2004b). The DOE model also assumes that much of the waste from potentially disrupted waste packages will be embedded in basalt, although the mechanics of this process are poorly known (Bechtel SAIC Company, LLC, 2004b). Although few details are provided, uranous oxide in the waste is thought to alter to a uranyl silicate phase such as soddyite during a potential basaltic intrusive event. Solubilities of uranyl silicates such as soddyite are lower than the solubilities of uranyl oxide hydrates such as schoepite (Bechtel

SAIC Company, LLC, 2003d). Nevertheless, DOE does not account for this potential waste alteration effect in the performance calculation and adopts the apparently conservative approach that the wasteform is unaffected during a potential igneous intrusive event (Bechtel SAIC Company, LLC, 2003a, 2004b). Thus, inflowing meteoric water following a potential igneous event could rapidly alter the uranous oxide in spent nuclear fuel to uranyl oxide hydrates such as schoepite (Bechtel SAIC Company, LLC, 2003d). This assumption is the same as adopted for the basecase hydrologic release model (Bechtel SAIC Company, LLC, 2003d, 2004b).

In addition to chemical alteration effects, potential basaltic igneous events may affect the physical characteristics of high-level waste. Basaltic magma temperatures are likely >1,000 EC [1,832 EF] and can occur under varying levels of oxygen fugacity (e.g., Bechtel SAIC Company, LLC, 2003c). These conditions may lead to the formation of transgranular fractures in the wasteform (e.g., NRC, 1996). Formation of such fractures could increase the wasteform dissolution rates. However, current DOE models and analyses have not considered the potential for transgranular fracturing during basaltic intrusive events (Bechtel SAIC Company, LLC, 2003a, 2004b).

Although DOE analyses have not examined the entire range of physical conditions likely during basaltic intrusive events and potential effects on wasteform alteration processes, the base case assumption for radionuclide solubilities appears reasonably conservative based on rapid schoepite formation with exposure to meteoric water (Bechtel SAIC Company, LLC, 2003d, 2004b). Nevertheless, DOE has not yet considered the mechanical effects of potential basaltic igneous events on the wasteform with regard to possible increases in transgranular fracturing. Because an increase in transgranular fracturing could lead to an increase in waste dissolution rates following an igneous intrusive event, DOE should provide information in any potential license application which either, demonstrates that transgranular fracturing will not significantly increase the rate of waste dissolution or, demonstrates that the mechanical effects on the wasteform from an intrusive event will not significantly increase transgranular fracturing. The NRC considers DOE's response to Agreement IA.2.20 to be insufficient to close this agreement at this time.

5.0 SUMMARY

Staff evaluated DOE's responses to four IA KTI agreements. These agreement responses are contained in Appendixes A–D to Bechtel SAIC Company, LLC (2003a). The specific agreements evaluated were IA.2.03 AIN-1, 2.09 AIN-1, 2.19, and 2.20. Staff concludes the information provided by DOE satisfies the intents of Agreements IA.2.03 AIN-1 and 2.09 AIN-1. Additional information is needed, however, to satisfy the intent of Agreement IA.2.19 with regard to gas-flow modeling during potential basaltic intrusive events. Additional information is also needed to satisfy the intent of Agreement IA.2.20 with regard to possible transgranular fracturing of waste during potential basaltic intrusive events.

6.0 STATUS OF THE AGREEMENT

Based on the preceding review, the information provided by DOE satisfies the intent of IA KTI Agreements IA.2.03 AIN-1 and 2.09 AIN-1. Therefore, NRC considers those agreements complete. Because information provided by DOE does not appear to satisfy the intent of IA.2.19 and 2.20, the NRC considers the status of these agreements as needing additional information. NRC will review any relevant information submitted, as part of its review of a License Application with regard to regard to gas-flow modeling during potential basaltic intrusive events, and possible transgranular fracturing of waste during potential basaltic intrusive events.

7.0 REFERENCES

Bechtel SAIC Company, LLC. "Atmospheric Dispersal and Deposition of Tephra from a Potential Volcanic Eruption at Yucca Mountain, Nevada." MDL–MGR–GS–000002. Rev. 00. Las Vegas, Nevada: Bechtel SAIC Company, LLC. 2004a.

———. "Igneous Intrusion Impacts on Waste Packages and Waste Forms." ANL–EBS–GS–000002. Rev. 1. Las Vegas, Nevada: Bechtel SAIC Company, LLC. 2004b.

———. "Technical Basis Document No. 13: Volcanic Events." Rev. 2. Las Vegas, Nevada: Bechtel SAIC Company, LLC. 2003a.

———. "Characterize Framework for Igneous Activity at Yucca Mountain, Nevada." ANL–MGR–GS–000001. Rev. 1. Las Vegas, Nevada: Bechtel SAIC Company, LLC. 2003b.

———. "Characterize Eruptive Processes at Yucca Mountain, Nevada." ANL–MGR–GS–000002. Rev. 1. Las Vegas, Nevada: Bechtel SAIC Company, LLC. 2003c.

———. "Dissolved Concentration Limits of Radioactive Elements." ANL–WIS–MD–000010. Rev. 2. Las Vegas, Nevada: Bechtel SAIC Company, LLC. 2003d.

CRWMS M&O. "Characterize Eruptive Processes at Yucca Mountain, Nevada." ANL–MGR–GS–000002. Rev. 00. Las Vegas, Nevada: DOE, Yucca Mountain Site Characterization Office. 2000a.

———. "Total System Performance Assessment for the Site Recommendation." TDR–WIS–PA–000001. Rev. 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. 2000b.

———. "Dike Propagation Near Drifts." ANL–WIS–MD–000015. Rev. 00 ICN 01. North Las Vegas, Nevada: DOE, Yucca Mountain Site Characterization Office. 2000c.

———. "Waste Package Behavior in Magma." CAL–EBS–ME–000002. Rev. 00. Las Vegas, Nevada: DOE, Yucca Mountain Site Characterization Office. 2000d.

DeGraff, J.M., and A. Aydin. "Effect of Thermal Regime on Growth Increment and Spacing of Contraction Joints in Basaltic Lava." *Journal of Geophysical Research*. Vol. 98. pp. 6,411–6,430. 1993.

Mohanty, S., R. Codell, J.M. Menchaca, R. Janetzke, M. Smith, P. LaPlante, M. Rahimi, and A. Lozano. "System-Level Performance Assessment of the Proposed Repository at Yucca

Mountain Using the TPA Version 4.1 Code." CNWRA 2002-05. Rev. 2. San Antonio, Texas: CNWRA. 2004.
NRC. "Risk Insights Baseline Report." ML040560162. Washington, DC: NRC. April 2004. <www.nrc.gov/ waste/hlw-disposal/reg-initiatives/resolve-key-tech-issues.html>

———. NUREG–1804, "Yucca Mountain Review Plan—Final Report." Rev. 2. Washington, DC: NRC. July 2003.
———. NUREG–1762, "Integrated Issue Resolution Status Report." Washington, DC: NRC. July 2002.

———. "Issue Resolution Status Report, Key Technical Issue: Igneous Activity." Rev. 2. Washington, DC: NRC, Division of Waste Management. 1999.

———. NUREG–1565, "Dry Oxidation and Fracture of LWR Spent Fuels." Washington, DC: NRC, Division of Waste Management. November 1996.
Ratcliff, C.D., J.W. Geissman, F.V. Perry, B.M. Crowe, and P.K. Zeitler. "Paleomagnetic Record of a Geomagnetic Field Reversal from Late Miocene Mafic Intrusions, Southern Nevada." *Science*. Vol. 266. pp. 412–416. 1994.

Reamer, C.W. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Igneous Activity (September 5, 2001)." Letter (September 12) to S. Brocoum, DOE. Washington, DC: NRC. 2001a. <http://www.nrc.gov/waste/hlw-disposal/public-involvement/mtg-archive.html#KTI>

———-. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Igneous Activity (June 21–22, 2001)." Letter (June 29) to S. Brocoum, DOE. Washington, DC: NRC. 2001b. <http://www.nrc.gov/waste/hlw-disposal/public-involvement/mtg-archive.html#KTI>

Rosseau, J.P., E.M. Kwicklis, and D.C. Giles. "Hydrogeology of the Undersaturated Zone, North Ramp Area of the Exploratory Studies Facility, Yucca Mountain, Nevada." U.S. Geological Survey. Water Resources Investigations Report 98-4050. p. 259. 1999.

Schlueter, J.R. "Igneous Activity Agreement 2.09, Additional Information Needed." Letter (February 13) to J.D. Ziegler, DOE. Washington, DC: NRC. 2003. <http://www.nrc.gov/reading-rm/adams.html>

———. "Igneous Activity Agreement 2.03." Letter (November 12) to J.D. Ziegler, DOE. Washington, DC: NRC. 2002. <http://www.nrc.gov/reading-rm/adams.html>

———-. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Igneous Activity (August 29–31, 2000)." Letter (October 23) to S. Brocoum, DOE. Washington, DC: NRC. 2000. <http://www.nrc.gov/waste/hlw-disposal/public-involvement/mtg-archive.html#KTI>

Travers, W.D. "Final Staff Response to March 19, 2003, Requirements Memorandum on the Waste Arena Briefing—M030303A." Letter (June 5) to Chairman Diaz, Commissioners Dicus, McGaffigan, and Merrifield. Washington, DC: NRC. 2003. <http://www.nrc.gov/reading-rm/adams.html>

Ziegler, J.D. “Transmittal of Report Addressing Igneous Activity (IA) Key Technical Issue (KTI) Agreement Item 2.03.” Letter (July 30) to J.R. Schlueter, NRC. Las Vegas, Nevada: DOE. 2002a. <http://www.nrc.gov/reading-rm/adams.html>

———. “Transmittal of Report Addressing Igneous Activity (IA) Key Technical Issue (KTI) Agreement Items 2.02 and 2.09.” Letter (June 27) to J.R. Schlueter, NRC. Las Vegas, Nevada: DOE. 2002b. <http://www.nrc.gov/reading-rm/adams.html>