KESA VA INPUT: REPOSITORY PERFORMANCE: DIRECT RELEASE AND TRANSPORT (VOLCANIC DISRUPTION OF THE WASTE PACKAGE, AND AIRBORNE TRANSPORT OF RADIONUCLIDES)

CONCERN

TSPA-VA analyses significantly underestimate public health and safety risks associated with future igneous activity at the proposed repository site. Many models and data used to support TSPA-VA analyses do not meet NRC acceptance criteria and DOE has no apparent plans to conduct additional investigations necessary to support igneous event risk assessments in licensing. Unavailability of acceptable models to support igneous activity risk assessments presents a concern, in that a process with major contributions to total system risk would not be supported adequately in the license application.

IMPORTANCE

DOE concludes in the TSPA-VA that there are no risks from volcanism during a 10,000 yr post closure period, based on models assuming waste package resilience and limited HLW entrainment during a volcanic eruption (CRWMS M&O, 1998). NRC review concludes (i) these analyses are based on assumptions of physical conditions that are not representative of Yucca Mountain basaltic volcanism, (ii) data are insufficient to evaluate waste package and HLW behavior under appropriate physical conditions, and (iii) model assumptions are incongruent with those used elsewhere in the TSPA-VA, for example, in enhanced source-term analyses.

Current NRC calculations, which take into account significant model and parameter uncertainties, indicate this probability-weighted risk from volcanic disruption of the proposed repository exceeds by 1–2 orders of magnitude the risk from normal (i.e., undisturbed) repository operations (e.g., NRC, 1998a). Volcanic disruption thus represents a very significant risk component for post-closure public health and safety. The NRC considers that key models and data used to support DOE conclusions will not meet acceptance criteria for igneous activity (i.e., NRC, 1998b). Low probability, potentially high-consequence events such as igneous activity will need to be supported in licensing by models and data with a technical quality similar to that used for high probability, low-consequence events. Information in the TSPA-VA indicates that DOE plans to gather no additional data in this area, and only plans a minor program of model refinement (DOE, 1998, sections 2.2.7.1 and 4.3.3.1). The DOE program, therefore, appears to be insufficient to resolve NRC concerns related to igneous activity before licensing.

STATUS OF RESOLUTION

Although DOE concludes in the TSPA-VA that the probability subissue is resolved, significant differences are not addressed between proposed probability models and the NRC position that an annual probability of 10^{-7} for volcanic disruption is suitable for resolution (NRC, 1997, 1998b). NRC notes that models (e.g., Ho, 1992) and supporting data (e.g., Wernicke et al., 1998) are available in the peer-reviewed literature that suggest the annual probability for volcanic disruption may exceed 10^{-6}, thus, NRC does not view a probability of 10^{-7} as unduly conservative. While acknowledging in the TSPA-VA that an intrusion probability of 10^{-7} may represent an upper bound, DOE concludes that the average annual probability of volcanic disruption is 6×10^{-9}. These event probabilities are cited in the TSPA-VA as justification for not conducting additional technical investigations, suggesting DOE is using average annual probabilities as a scenario screening criterion rather than due consideration of the reasonable upper range of model variability.

Recent informal staff interactions discussed technical bases to support a DOE average annual volcanic disruption probability of 1.5×10^{-8}, with an upper bound extending to 10^{-7}. If implemented by DOE, this value represents a path forward as the probability of volcanic disruption is high enough to warrant consideration by DOE as a credible scenario for licensing. In licensing, however, DOE will still need to address NRC concerns with acceptable technical bases for probability models $<10^{-7}$, in order to resolve significant differences with some probability models in the peer-reviewed literature.

Models for interactions between igneous events and engineered barrier systems contain significant uncertainties, as the physical conditions associated with igneous systems are well beyond the design bases for normal repository conditions. Models for these interactions presented in TSPA-VA do not address these uncertainties, nor do they consider physical conditions appropriate for YMR igneous events (CRWMS M&O, 1998, section 10.4.2.3). In addition, the TSPA-VA analyses do not meet many NRC acceptance criteria and at times are inconsistent with models presented elsewhere in the TSPA-VA (cf. CRWMS M&O, 1998, section 10.4.3.3). The results of these TSPA-VA analyses, however, are used by DOE to conclude that further work on igneous event consequence is not warranted. DOE will need to address staff concerns regarding igneous event consequences before licensing in order to achieve meaningful issue resolution. Specifically, models indicating waste package resilience and lack of HLW entrainment during igneous events will need to be supported by data and analyses that examine physical conditions representative of YMR igneous events (NRC, 1998b). Collecting data and constructing models that will meet NRC acceptance criteria before licensing should be achievable, if sufficient priority is assigned to these tasks.

ADDITIONAL BACKGROUND

NRC concerns with the DOE igneous activity program, including the relationship to Total System Performance Assessment modeling, have been raised in comments on DOE study plans 8.3.1.8.1.1 (Holonich, 1994a), 8.3.1.8.1.2 (Holonich, 1994b), 8.3.1.8.5.1 (Holonich, 1994c), numerous interactions with DOE at Technical Exchanges, Appendix 7 Meetings, meetings and workshops with the Advisory Committee on Nuclear Waste and the Nuclear Waste Technical Review Board, interactions associated with the DOE PVHA, and most recently through detailed comments in the Igneous Activity Issue Resolution Status Reports (NRC, 1997, 1998b). Acceptance criteria contained in the IA IRSR (NRC, 1998b) delineate an acceptable technical basis for evaluating risks associated with future igneous events.

BASIS

Igneous activity in the YM region consists of emplacement of subsurface bodies or intrusions, which in turn can reach the surface and form volcanoes. Intrusive events can disrupt waste packages but do not transport HLW to the surface. In contrast, volcanic events transport HLW from breeched waste packages directly into the accessible environment during the eruption. These distinctions are important because there are different probabilities and dose consequences associated with intrusive and volcanic events. The TSPA-VA often transposes the 1.5×10^{-8} annual probability of an intrusion directly intersecting the proposed repository site (e.g., CRWMS M&O, 1998) with the probability of a volcano forming through the repository. Analyses presented in the TSPA-VA conclude the assumed probability of a volcano forming through the proposed repository site is 6×10^{-9}. This low probability could then be used as justification to screen-out volcanic disruption as a credible disruptive event for TSPA-LA (i.e., TSPA-VA section 4.4.2 and CRWMS M&O section 10.2). Excluding volcanic disruption from the TSPA-LA would present a clear licensing concern, as NRC analyses have shown that this disruptive process presents non-negligible risks to public health and safety.

DOE relies upon source-zone probability models that restrict the location of future volcanic events to areas west of the proposed repository site. Although tectonic models were not used during the PVHA elicitation to define these source-zones, TSPA-VA uses a tectonic source-zone model that is not reasonably consistent with tectonic models used by other project staff in Probabilistic Seismic Hazards Assessment studies or in other tectonic modeling tasks. These other models consider that Crater Flat and Yucca Mountain are part of the same tectonic province or structural basin. In addition, the TSPA-VA volcanic source-zone model would not meet NRC acceptance criteria as it is not consistent with many observed tectonic features and geophysical data in the area, and does not provide a mechanical basis as to how the proposed tectonic regime would localize ascending magma away from the repository site. Although expert opinion is an acceptable method to construct models, other probability models are presented in the peer-reviewed literature that use expert opinion to construct source-zones that encompass the proposed repository site. These models conclude the annual probability of volcanic disruption is on the order of 10^{-6} (e.g., Ho, 1992). Recent analyses of tectonic strain-rate by Wernicke et al. (1998) also conclude that igneous event recurrence rates are underestimated in the YMR. This conclusion also is supported by Earthfield (1995), which concludes around 30 previously unrecognized igneous features are buried in the subsurface within 30 km of YM. Although staff has presented (Connor et al., 1998) alternative interpretations to Wernicke et al. (1998), their hypothesis relating strain rate and volcanism recurrence rate cannot be refuted confidently with available data and thus presents a measure of reasonable doubt on the uncertainty associated with all published probability estimates. Based on due consideration of these issues, the results of its independent analysis, and the results of DOE source-zone models, NRC concludes an annual probability of 10^{-7} presents a reasonably conservative estimate for volcanic disruption of the proposed repository site.

In TSPA-VA, the lack of HLW release following a repository-penetrating volcanic event is based on several key assumptions. First, it is assumed that a waste package with >50 percent of the original corrosion resistant material thickness (i.e., >1 cm) will not fail when exposed to the extreme physical conditions of a volcanic eruption except through occasional end-cap failure. This assumption precludes any direct HLW entrainment or release from any volcanic event occurring within the first 100,000 yr post-closure (CRWMS M&O, 1998). This assumption is based on subjective extrapolation of limited data from <430 °C to likely magmatic temperatures around 1100 °C. In contrast, similar data are used to conclude that an intact waste package will fail mechanically when exposed to magma intruded into repository drifts (i.e., enhanced source-term analysis), even when temperatures significantly below expected intrusion temperatures are used in the analysis (CRWMS M&O, 1998). The TSPA-VA analysis of waste-package resilience also does not address the dynamic force imposed on a waste package entrained into a volcanic conduit and impacted by molten rock with a density around 2600 kg/m^3 flowing at velocities of 10–100 m/s for days to weeks. As outlined in the IA IRSR (NRC, 1998b), staff analyses of limited available data conclude waste-package breech is likely under volcanic eruption conditions. Models proposing waste-package resilience during igneous events are inherently nonconservative and will need robust support through analyses and data that examine physical, chemical, and thermal conditions representative of likely future igneous activity in the YM region. Such analyses are not presented in the TSPA-VA.

Another key assumption in the TSPA-VA that is not supported by available information is that magma particle sizes or particle velocities are insufficient to entrain HLW fragments. Although the expansion of dissolved volatiles in ascending magma may be sufficient to form a two-phase flow regime at repository depths, the fragmented particles are still at temperatures around 1100 °C. Particles will be larger average size than observed at completely cooled and fragmented fall deposits, and will impact HLW fragments elastically. In addition, assumed HLW particle sizes do not account for the extreme physical conditions associated with igneous disruption. As outlined in the IA IRSR (NRC, 1998b), staff concludes that HLW particle sizes will be reduced substantially when exposed to the hostile physical, thermal, and chemical environment associated with YM igneous events. Models proposing a lack of entrainment ability in future repository-penetrating igneous events will need robust support through analyses and data that examine physical, chemical, and thermal conditions representative of likely future igneous activity in the YM region.

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Repository Performance: Direct Release and Transport (Volcanic Disruption of the Waste Package, and Airborne Transport of Radionuclides)

Brittain E. Hill, John S. Trapp, and Charles B. Connor

Concern:

TSPA-VA analyses significantly underestimate public health and safety risks associated with future igneous activity at the proposed repository site. Many models and data used to support TSPA-VA analyses do not meet NRC acceptance criteria and DOE has no apparent plans to conduct additional investigations necessary to support igneous event risk assessments in licensing. Unavailability of acceptable models to support igneous activity risk assessments presents a concern, in that a process with major contributions to total system risk would not be supported adequately in the license application.

Importance:

DOE concludes in the TSPA-VA that there are no risks from volcanism during a 10,000 yr post closure period, based on models assuming waste package resilience and limited HLW entrainment during a volcanic eruption (CRWMS M&O, 1998). NRC review concludes (i) these analyses are based on assumptions of physical conditions that are not representative of Yucca Mountain basaltic volcanism, (ii) data are insufficient to evaluate waste package and HLW behavior under appropriate physical conditions, and (iii) model assumptions are incongruent with those used elsewhere in the TSPA-VA, for example, in enhanced source-term analyses.

Current NRC calculations, which take into account significant model and parameter uncertainties, indicate this probability-weighted risk from volcanic disruption of the proposed repository exceeds by 1–2 orders of magnitude the risk from normal (i.e., undisturbed) repository operations (e.g., NRC, 1998a). Volcanic disruption thus represents a very significant risk component for post-closure public health and safety. The NRC considers that key models and data used to support DOE conclusions will not meet acceptance criteria for igneous activity (i.e., NRC, 1998b). Low probability, potentially high-consequence events such as igneous activity will need to be supported in licensing by models and data with a technical quality similar to that used for high probability, low-consequence events. Information in the TSPA-VA indicates that DOE plans to gather no additional data in this area, and only plans a minor program of model refinement (DOE, 1998, sections 2.2.7.1 and 4.3.3.1). The DOE program, therefore, appears to be insufficient to resolve NRC concerns related to igneous activity before licensing.

Status of Resolution:

Although DOE concludes in the TSPA-VA that the probability subissue is resolved, significant differences are not addressed between proposed probability models and the NRC position that an annual probability of 10^{-7} for volcanic disruption is suitable for resolution (NRC, 1997, 1998b). NRC notes that models (e.g., Ho, 1992) and supporting data (e.g., Wernicke et al., 1998) are available in the peer-reviewed literature that suggest the annual probability for volcanic disruption may exceed 10^{-6}, thus, NRC does not view a probability of 10^{-7} as unduly conservative. While acknowledging in the TSPA-VA that an intrusion probability of 10^{-7} may represent an upper bound, DOE concludes that the average annual probability of volcanic disruption is 6×10^{-9}. These event probabilities are cited in the TSPA-VA as justification for not conducting additional technical investigations, suggesting DOE is using average annual probabilities as a scenario screening criterion rather than due consideration of the reasonable upper range of model variability. Recent informal staff interactions discussed technical bases to support a DOE average annual volcanic disruption probability of 1.5×10^{-8}, with an upper bound extending to 10^{-7}. If implemented by DOE, this value represents a path forward as the probability of volcanic disruption is high enough to warrant consideration by DOE as a credible scenario for licensing. In licensing, however, DOE will still need to address NRC concerns with acceptable technical bases for probability models $<10^{-7}$, in order to resolve significant differences with some probability models in the peer-reviewed literature.

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Basis:

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4.4.2 and CRWMS M&O section 10.2). Excluding volcanic disruption from the TSPA-LA would present a clear licensing concern, as NRC analyses have shown that this disruptive process presents non-negligible risks to public health and safety.

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