UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON NUCLEAR WASTE AND MATERIALS
WASHINGTON, D.C. 20555-0001

February 26, 2008

The Honorable Dale E. Klein
Chairman
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: POSTCLOSURE DEGRADATION OF EMPLACEMENT DRIFTS AND ITS IMPACT ON ENGINEERED BARRIER SYSTEM PERFORMANCE AT THE PROPOSED YUCCA MOUNTAIN HIGH-LEVEL RADIOACTIVE WASTE REPOSITORY

Dear Chairman Klein:

At the 184th meeting of the Advisory Committee on Nuclear Waste and Materials (ACNW&M or the Committee), the staff of the NRC and the Center for Nuclear Waste Regulatory Analyses (CNWRA) presented their current understanding of drift degradation and its impact on engineered barrier system performance at the proposed Yucca Mountain high-level radioactive waste repository. The staff further briefed the Committee on its approach and ability to review the U.S. Department of Energy (DOE) analysis of drift (tunnel) stability in a potential license application. At the 185th meeting of the Committee, the Electric Power Research Institute (EPRI) presented an overview of its recent analyses of drift degradation. In addition, representatives of the ACNW&M attended a public technical interaction under Appendix 7 rules between the NRC and DOE on this topic in October 2007.

BACKGROUND

Rock formations surrounding emplacement drifts in the proposed repository will be subject to thermal, seismic, and excavation-induced stresses over the lifetime of the repository. The rock walls of the drifts may fail if these stresses exceed the strength of the rock and cause the accumulation of rock rubble that could adversely impact the performance of the repository.

The DOE plans to install ground support in the drift to provide stable underground openings during preclosure operations. However, the DOE does not plan to take credit for these supports beyond the preclosure period. Thus, drift instability leading to rock rubble accumulation during the postclosure regulatory period could affect the engineered barriers' performance and influence thermal, hydrologic, and igneous activity processes in the emplacement drift environment. These effects are likely to change along the length of the drifts because of spatially varying properties of the host rock.

The current understanding of drift stability processes is that the dynamic impact of individual rocks falling on the drip shields covering the waste packages is likely to have a small to negligible effect on repository performance. However, the static load of rock rubble accumulation from a gradual change in drift configuration (drift degradation) could adversely affect the repository performance as the result of enhanced corrosion and buckling of the drip shields. Subsequent potential mechanical damage to waste packages could occur from vibratory motion during seismic events because of interaction between buckled drip shields and waste packages (NRC) and among waste packages (DOE). Over long time periods, the resulting mechanical damage could lead to enhanced corrosion of waste packages.

STATUS OF DRIFT DEGRADATION ANALYSES

The NRC staff and its contractor, CNWRA, have been analyzing drift stability in preparing for the NRC review of the pending license application for repository construction (e.g., Ofoegbu et al., 2006). The CNWRA recently published a report (CNWRA, 2007) describing its current understanding of the DOE position on drift degradation and its effects on repository performance as well as the results of the CNWRA analyses on drift degradation. The CNWRA concludes from its analyses that "…(i) repository thermal loading (based on current DOE design concept) alone could cause degradation of the emplacement drifts and significant accumulations of rock rubble within approximately 1000 years after closure and (ii) the drip shield, as currently designed, could collapse onto the waste package as a result of static or seismic loading and creep from the accumulated rock rubble." The CNWRA analyses assume that progressive spalling (repeated removal of thin curved surface rock slabs) caused by overstress in the roof of the drifts as the result of thermal stresses will continue until the volume of the drift and the cavity caused by roof collapse is rubble filled.

The NRC staff has described its approach to reviewing drift stability in the pending license application including development of parameter distributions for abstractions in the NRC's Total-System Performance Assessment (TPA) code (version 5.1). Abstractions in TPA version 5.1 consider the potential long-term effects of drift degradation primarily resulting from thermal stress but also from seismic stresses on the performance of engineered barriers as reported by CNWRA (2007). The NRC staff is continuing its independent analyses to develop a risk-informed understanding of the drift degradation process and the resulting effects on the engineered barriers system.

In contrast to the CNWRA conclusion that spalling of slabs of rock from the drift during the repository's thermal maximum will be the major cause of drift degradation, the DOE finds that vibrations associated with multiple, lower magnitude seismic events during the long compliance period of the repository are potentially the most significant factor. These conclusions lead to significant differences in the timing, rate, and effect of rock rubble accumulation and its potential impact on repository performance. The analyses supporting the views of the DOE and the results of its studies are being prepared for publication (a revision of BSC, 2004, is in progress) and will be incorporated in the pending construction license application.

EPRI (Kemeny et al., 2006; EPRI, 2005, 2006, and 2007a and b) has also evaluated the potential for drift degradation in waste emplacement drifts. The results of its analyses of thermal spalling in the drifts agree with the DOE findings (BSC, 2004) and partially agree with the CNWRA analyses in that the predicted regions of initial overstress are similar. However, the EPRI modeling of drift degradation does not predict that the drifts would be filled by rock rubble as a result of thermally induced degradation alone nor does it support the CNWRA view that progressive drift degradation will fill drifts relatively soon after repository closure.

OBSERVATIONS

The Committee makes the following observations:

- In a previous letter on drift stability (Garrick, 2004), the Committee recommended preparation of an evaluation of risk from the repository as the result of drift instability. Subsequently, the NRC staff has determined drift stability to be of medium significance to risk (NRC, 2004). The Committee is pleased to note that the staff is quantitatively evaluating the risk significance of the results of its analyses on drift degradation using TPA version 5.1 (CNWRA, 2007, p. 7-1).

- The Committee is pleased to note that the NRC staff reports that it will consider the full range of possible views on drift degradation caused by both thermal and seismic stresses in reviewing the license application. The NRC staff also reports that it will consider the potential effects of drift degradation on failure of the drip shields and waste packages.

- There is general agreement that thermally generated rock stresses will lead to spalling of the roof rocks of the repository drifts during the thermal maximum period. However, differences arise in the predicted timing, rate, and extent of this spalling because of uncertainties in the modeling methodologies and assumptions. A critical uncertainty leading to differences in current views is the assumption in the CNWRA analyses of continuous elastic strain, which leads to repeated spalling in newly exposed roof rock by successive rockfalls until the drift and the cavity developing over it will be choked with rubble (progressive spalling). This could be an overly conservative assumption because it fails to consider the possibility that spalling may be arrested not only by the openings becoming filled with rubble, but by other mechanisms as well (Ofoegbu et al., 2006). For example, the openings may develop into an elliptical configuration leading to a minimum-energy state that prevents additional overstressing and spalling (e.g., Martin, 1997), or the fractured rock mass around the perimeter of the drift may retain sufficient residual strength (e.g., EPRI, 2007a and b) to prevent rockfall.

- The lack of acceptable analogs and the long compliance period of the repository will require the NRC to rely largely on analytical approaches and theoretical modeling of drift degradation rather than on empirical evidence obtained from experience with underground openings. Over the past two decades, notable advances have occurred in the modeling of drift degradation as the result of spalling as evidenced in the recent modeling of DOE and EPRI. These modeling approaches contrast with the less realistic methodologies used in the CNWRA analyses.

- Input parameters pertinent to drift degradation in the NRC's TPA version 5.1 are based on average mechanical properties of the host rocks. This approach does not fully incorporate the properties of the host rocks that vary spatially; this variation could impact the performance assessment results.

- Validation of models used in analysis of drift degradation is important because of uncertainties in the modeling and input parameters. Validation is limited because of the lack of appropriate analogs for thermal and seismic stresses over the long periods of time involved in the lifetime of the repository. Drift degradation associated with the drift-scale heater test in the Exploratory Studies Facility at Yucca Mountain is generally agreed to be the most suitable analog for drift degradation model validation. However, the NRC staff is

concerned that thermal degradation was not considered in the design and analysis of the experiment and the test was of limited duration.

- The impact of drift degradation on repository performance is directed in current analyses toward the effect of rubble on corrosion and mechanical processes acting on the drip shields and ultimately the waste containers under the shields. However, the effects of drift degradation also may be relevant to other potential scenarios affecting repository performance. For example, if the drifts are assumed to be filled with rock rubble within the first few thousand years (NRC, 2007), this will have an impact on the consequences from a potential igneous intrusion into the repository. Rock rubble accumulation in the drifts would inhibit movement of igneous material into the drifts. Furthermore, coupling between thermal degradation of the drifts and seismic activity could have important implications. For example, vibratory motion associated with seismic events could initiate the fall of fractured rock of the overstressed drift roof that is stable because of residual strength, increasing the amount of rock rubble in the drifts.

RECOMMENDATIONS

The Committee makes the following recommendations:

- The Committee encourages the NRC staff to complete a quantitative assessment of the potential risk from the repository because of drift instability. This assessment should consider the relative merits of the differing views on thermal and seismic processes, the timing of drift degradation, and the effects on engineered barriers. A risk assessment that incorporates the full range of current views will lead to better understanding of the uncertainties in the degradation processes and their impact on the engineered barriers.

- The risk assessment associated with drift stability should use input parameters that reflect the spatial variability of the host rock properties. The result will be an enhanced risk-informed assessment.

- The staff should evaluate the full range of views of drift degradation mechanisms including those developed over the last few decades rather than focus on the method used in the current CNWRA analyses.

- The staff should broaden its consideration of the effects of drift stability on repository performance to evaluate coupled effects from igneous intrusion in addition to the seismic events and infiltrating water that are currently considered.

- The staff should support modeling approaches using analogs and experiments, including determining the extent to which heater tests in the Exploratory Study Facility at Yucca Mountain can be used for this purpose.

Sincerely,

/RA/

Michael T. Ryan
Chairman

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NRC

From: Michael T. Ryan, Chairman
ACNW&M

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