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U.S. Nuclear Regulatory Commission
ATTN: Dr. Mysore Nataraja
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TWFN, Mail Stop 7 C6
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Subject: The DOE Position on Drift Collapse

Dear Dr. Nataraja:

This letter is a follow-up to previous discussion between NRC and CNWRA staff and a summary of CNWRA staff opinion regarding the current DOE position on the long-term stability of emplacement drifts at the proposed Yucca Mountain repository. The DOE position on rockfall and drift collapse can be summarized as follows.

(1) With respect to potential direct mechanical effects of rockfall on performance, DOE intends to (i) design the drip shields and waste packages to withstand impact from a certain rock-block size (design basis), and (ii) screen out potential impacts from larger rock blocks on the basis that the probability of such impacts is smaller than the regulatory limit of 1 in 10,000 for 10,000 years.

(2) With respect to other potential effects of rockfall on performance, DOE intends to screen out drift collapse (i.e., degradation of shape, size, and other characteristics of the emplacements drifts) on the basis that its probability of occurrence is smaller than the regulatory limit.

The CNWRA staff examined the DOE position on rockfall and drift collapse to determine if it can be expected to produce an acceptable safety case regarding the effects of potential rockfall and drift collapse on the performance of a potential high-level waste repository at Yucca Mountain. In the opinion of the CNWRA staff, DOE is expected to make a satisfactory case regarding the capability of the waste-package and drip-shield design to withstand the "design-basis" rock impact, following a satisfactory completion of DOE/NRC agreements RDTME.3.17 and 3.18, and CLST.1.14, 2.03, 2.08, and 2.09. DOE is also expected to develop a satisfactory case for screening out impact from larger rock blocks, following a satisfactory completion of DOE/NRC agreement RDTME.3.19. The approach defined in RDTME.3.19 relies on conducting mechanical analyses of the progressive (and time-dependent) failure of the emplacement drifts to calculate the block size and frequency of rockfall. This kind of analysis is more demanding than an alternative approach that is based on statistical analyses of the fracture data and does not require a mechanical analysis of the underground openings. The alternative approach was discussed with DOE staff during the preparatory telephone meetings for the

February 2001 DOE/NRC technical exchange on the Repository Design and Thermal Mechanical Effects Key Technical Issue. The DOE staff, however, chose the more-demanding approach (i.e., progressive-failure analysis) because they believe that the results would help uphold the current DOE position that the drifts will not collapse.

In our opinion, it is unlikely that an acceptable technical basis can be developed to support the current DOE position on drift collapse, which is that the emplacement drifts will not experience significant collapse through the 10,000-year period of regulatory concern. An acceptable case for drift collapse would require information about the potential effects of drift collapse on repository performance. One implication of the DOE position on drift collapse is shown in Figure 1, which is a schematic illustration of the DOE abstraction of moisture flow through the repository horizon. The moisture flux that intersects the drift perimeter (i.e., the deep percolation flux, Q_p) is split into two parts: a part flows around the drift because of the capillarity of the drift opening and the remaining part (q_s) enters the drift opening. The quantities Q_p and q_s are evaluated based on an abstraction of results from process-model calculations that assume a fixed geometry for the emplacement drifts through the entire simulation period. The ratio q_s/Q_p used in DOE's performance assessment (CRWMS M&O, 2000a, Tables 8 and 11) varies with the deep percolation flux, but is generally smaller than 0.05 for values of Q_p of 15 mm/yr or smaller. That is, only 5% or less of the available deep percolation flux may seep into the emplacement drifts in the DOE performance assessment model. The other 95% or more is diverted around the drift because of the capillarity of the drift opening. An examination of Figure 1(b) indicates a serious cause for concern regarding how much of the initial capillary barrier associated with the drift opening can be assumed to be retained following the onset of drift collapse. As Figure 1(b) shows, the collapse of drifts would create several enlarged fracture spaces that would intercept capillary-held moisture and redirect it into the drift. As a result, the applicable values of the ratio q_s/Q_p may be significantly larger than the values used in DOE's performance assessment.

In addition to the potential effects on seepage, drift collapse may also cause increased temperature and mechanical loading of waste packages and drip shields. Broken rock deposited into the drift openings would provide some amount of insulation around the waste packages and drip shields, resulting in higher temperatures. For example, calculations performed by DOE to evaluate the effects of backfill indicate an increase in the maximum waste-package surface temperature from about 160°C for a no-backfill case to about 290°C for a backfilled case with the same thermal loading (Leem and Dunlap, 2001). The increased temperature would cause a decrease in the mechanical strength of the drip-shield and waste-package materials. The yield strength of titanium grade 7, for example, decreases from about 276 MPa at 100°C to about 174 MPa at 149°C (ASME, 1995). The integrity of fuel cladding may also be compromised depending on how high the waste-package temperature may rise and for how long the temperatures would be that high. Waste packages and drip shields would also be subjected to increased mechanical loading from the dead weight of broken rock. The result would be an increased potential for mechanical failure of the drip shields from immediate buckling or creep, which would compromise the ability of the drip shields to perform their intended function of protecting waste packages from dripping water.

Both the type and degree of drift collapse are likely to vary with time and with rock-mass characteristics as illustrated schematically in Figure 2. For example, the collapsed shapes in Figure 2(b) and (c) may result if collapse is controlled by near-vertical fractures whereas the shape in (d) would result if collapse is controlled by horizontal fractures. The extent of the failure zone and the volume of broken rock that would accumulate in the opening depend on several rock-mass characteristics, such as fracture frequency and orientation, and rock strength. The variability of collapsed-drift characteristics illustrated in Figure 2 indicates that the calculated significance of drift collapse to repository performance would be affected by the assumptions made regarding the timing and rate of drift collapse and the extent of the associated rock failure.

Finally, in our opinion, there is overwhelming evidence against the current DOE position on drift collapse (i.e., that the emplacement drifts would retain their as-built shape and size for 10,000 years). The DOE position on drift collapse goes against a fundamental philosophy of underground-space design: an excavated underground opening in a fractured (or unfractured but weak) rock mass needs to be provided with an adequate ground-support system and sufficient maintenance of the ground support in order to ensure stability of the opening through its required service life. The anticipated stand-up time for an unsupported opening in fractured rock would typically vary from a few hours in poor-quality rocks to a few months in good quality rocks (cf. Hoek and Brown, 1980). In other words, an argument for the stability of an excavated opening in fractured rock can be made if such an opening is provided with adequate ground support, and only for the period during which the maintenance of such ground support can be assured. The results of thermal-mechanical analyses performed by CNWRA staff to evaluate proposed emplacement-drift designs for Yucca Mountain indicate that ground support would be needed to prevent failure of the emplacement drifts. These results are consistent with the recent observation of rock raveling from the roof area of the DOE drift-scale test opening, as well as with an opinion expressed by a DOE expert panel on drift stability (Brekke et al., 1999), that all of the drifts are likely to collapse within the period of regulatory concern. For these reasons, we are unable to anticipate that an acceptable technical basis can be developed to support the DOE position that the proposed emplacement drifts would retain their integrity for 10,000 years notwithstanding that maintenance of the drifts would be provided for no more than 50–300 years. We believe that an acceptable case on drift collapse may be developed through an evaluation of the potential effects of drift collapse on seepage, temperature, and mechanical loading; and accounting for such effects, as necessary, in the evaluation of the ultimate measure of repository performance.

If you have any questions concerning this letter, please contact Goodluck Ofoegbu at (210) 522-6641 or me at (210) 522-5151.

Sincerely,

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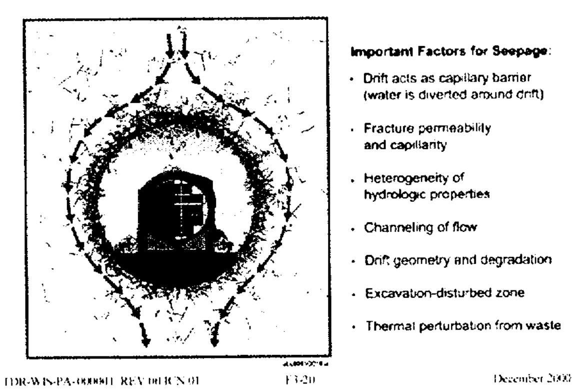

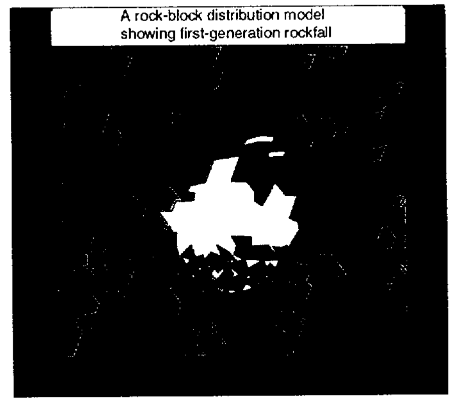

Figure 1. Left plot, (a) Schematic illustration of DOE abstraction of moisture flow through the repository horizon (CRWMS M&O, 2000b, p. F3-20); right plot, (b) onset of drift collapse from a simulation of the effects of seismic loading on excavated openings in a fractured rock mass (Hsiung et al., 2001).

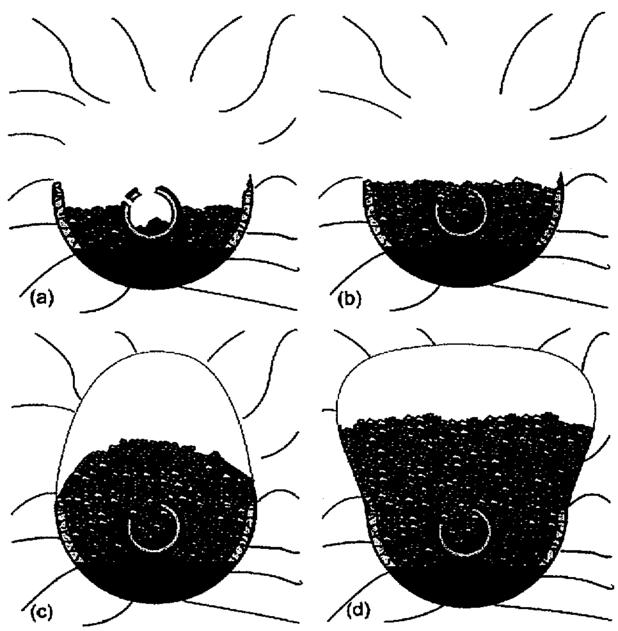

Figure 2. Schematic illustration of the variability of collapsed-drift characteristics. Case (a) may indicate the early stages of drift collapse or the advanced stages in an essentially unfractured rock; cases (b) and (c) represent collapse controlled by vertical fractures, with case (c) representing a more advanced stage; case (d) represents collapse controlled by horizontal fractures.

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