Department of Energy
Carlsbad Field Office
P. O. Box 3090
Carlsbad, New Mexico 88221

June 29, 2001

Mr. Frank Marcinowski
Office of Radiation and Indoor Air
U.S. Environmental Protection Agency
401 M. Street, S. W.
Washington, DC 20460

Dear Mr. Marcinowski:

This letter transmits additional information requested in your letter dated June 22, 2001 concerning a proposed change in the utilization of Panel 1 at the Waste Isolation Pilot Plant (WIPP).

Upon further consideration, we have determined that placement of CH-TRU waste containers in either 1- or 2-high stacks is not efficient because of floor conditions in the rooms. The floors are presently in such condition that they will have to be milled to a level condition to allow any waste emplacement. If a particular room is to be utilized, it is much more efficient to remove enough of the floor to stack 3-high as a part of the floor-leveling operation. Accordingly, we are no longer requesting the authority to stack CH-TRU waste containers 1- or 2-high and we have not supplied the additional information you requested to support approval of that request.

DOE is now requesting the flexibility to make only the following changes at WIPP:

- Use all, part or none of the space in each of the rooms in Panel 1 for CH-TRU waste disposal.

- Close Panel 1 without emplacing any RH-TRU waste.

The enclosure contains additional information requested regarding these two remaining changes. As discussed in our initial request dated April 26, 2001, the proposed change will allow the DOE to optimize the utilization of Panel 1 based on considerations of worker safety, operational efficiency and cost. Adding the flexibility included in the proposed change will allow the DOE to minimize the worker risk associated with re-mining and maintaining the back (roof) and ribs (sides) of the older excavations and will also improve operational efficiency. Finally, our analyses continue to demonstrate that these changes are non-significant, and that the proposed changes will not significantly change the certified baseline or compromise repository performance.

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At the present rate of waste receipt, DOE will have to cease waste disposal in Panel 1 to avoid blocking access to room 6 by July 31, 2001 if authorization to bypass room 6 is not granted by then. Under these circumstances, we request that you act separately on the request to bypass rooms in Panel 1, if necessary, to expedite action on that portion of our request.

If you have any questions, please contact Daryl Mercer at (505) 234-7452.

Sincerely,

Roger A Nelson for Dr. Inés Triay

Dr. Inés R. Triay
Manager

Enclosure

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CBFO:ORC:DM:VW:01-0797:UFC:5822

1. Roof Fall Analysis:

This request for additional information specifically pertains to stacking CH-TRU waste containers 1- or 2-high. This information is no longer needed because DOE has withdrawn its request for the flexibility to stack 1- or 2-high.

2. Backfill:

This request for additional information also specifically pertains to stacking 1- or 2-high and is no longer needed because DOE has withdrawn its request for the flexibility to stack 1- or 2-high.

3. Impact of Unused Rooms:

"You state that, "If rooms are left open, they will close to a condition equivalent to unmined salt." (Section 3.5) Justify this assumption. What evidence do you have to support this conclusion?

It is clear that you assume that an unused Room will close to become equivalent to unmined salt. Has your evaluation also considered the possibility that an empty room may act as a preferential pathway for fluid to enter the repository in the event of an intrusion borehole? Please explain how this scenario for intrusion is or is not plausible.

Disposal rooms close rapidly. This was observed in the WIPP underground where approximately one meter of closure occurred in Panel 7 between 1988 and 1998. Closure calculations of several experiments conducted at WIPP have demonstrated that the magnitude of creep closure can be accurately modelled. These large-scale experimental results were used to validate geomechanical models. The technical community, including the NRC WIPP Panel (1996), concur that predicted closure rates have a relatively small uncertainty and the magnitude of deformation is captured adequately by the models. The expectation that room closure leads to waste entombment underlies the scientific foundation for disposal in salt.

There is a large body of empirical evidence that abandoned rooms in working salt and potash mines continue to close with time, and eventually close completely to a condition equivalent to that of the unmined rock. This is particularly evident in some of the deep potash mines in Saskatchewan where previously mined rooms close quickly. Mraz et. al (1996), for example, have published data on closure rates in rooms at the K2 mine of IMC showing rapid closure continuing several years after mining. Where rooms have been backfilled, the reconstitution to native salt conditions is even more rapid. During a recent workshop in Carlsbad, Dr. Peter Breidung of Kali und Salz GmbH (Germany) noted that their disposal operations and production mines commonly backfill rooms and shafts which reconsolidate to *in situ* conditions (Breidung, 2001). In fact, Kali und Salz operations have mined back through old workings and the backfilled zones are essentially indistinguishable for the native rock. Similar results are known from salt mines in German domes, including the Asse mine.

This evidence from working mines is compelling, although it may not be directly applicable to the WIPP since the extraction ratios at WIPP are much lower and closure rates correspondingly slower. Thus, while the total closure of WIPP rooms is expected, it will take longer to occur than closure in operating salt or potash mines. In order to estimate the times needed for complete closure under WIPP conditions, it is necessary to rely on model predictions. The modelling results are summarized in the following paragraphs. They include calculations on empty rooms, which were conducted as the WIPP underground was being constructed, as well as later calculations on the closure of rooms backfilled with materials such as salt or waste. Note that these latter calculations are relevant since collapse of material from the roof, floor and ribs will approximate the salt-backfill case.

Room closure can be quantified by geomechanical modeling. Response of the underground is conventionally modeled using the finite element method (FEM). Many pertinent analyses of waste rooms have been performed (e.g., Morgan, 1987, Callahan and DeVries, 1991 and Stone, 1997). Morgan's analysis of closure of an empty single room using SANCHO (a precursor of SANTOS) estimated total room closure in 195 years (Figure 1), without simulating the effects of roof collapse and floor heave. The analyses by Stone used the FEM code SANTOS. Figure 2 is a plot referenced by Stone, which illustrates room closure rates (although this particular calculation simulates the presence of WIPP waste in the room). Porosity is reduced to about 8% in approximately 100 years. As salt-backfilled rooms or empty rooms approach total closure, permeability will reduce asymptotically to values equivalent to those of intact salt ($K<10^{-19}$ m^2). This estimate of re-consolidated salt permeability (K) derives from a relationship between permeability and density, which was developed for the shaft seal system design (Sandia, 1996).

If disposal rooms are left open and unsupported or roof bolted, creep closure and structural response will include floor heave and roof fall. With creep closure the empty (no WIPP waste) room would close around disaggregated material derived from the damaged rock in the roof, floor and ribs. Halite consolidation would then be the primary mechanism of porosity reduction. Callahan and DeVries calculated the closure of backfilled rooms, which are equivalent in many ways to an empty room filled with debris. They calculated mean stress development for rooms containing various backfill materials, which usually exceeded 10 MPa in 200 years. Salt debris subjected to such stress conditions would be well consolidated. Evidence from many studies indicates re-consolidation is effective and rapid (Mellegard et al., 1998) under conditions of modest mean stress (of the order of 5 MPa). Thus, the closing room would provide ample stress to reconsolidate the salt aggregate.

This scenario holds when some of the debris in the formerly empty room includes anhydrite from Marker Bed 139 and anhydrite a and b, since the anhydrite material will be encapsulated in broken salt. These processes of stress induced consolidation and fracture healing will ensure that the rooms return to close to their unmined state within a few hundred years. It should also be noted that there are numerous examples of rooms in operating mines totally closing in short periods of time (years). While the conditions in these mines are generally more severe than at the WIPP, since the extraction ratios, and thus the pillar loading are much higher, these differences will only affect the timing of the closure, not its eventual occurrence.

If rooms in Panel 1 were filled with mined salt, the granular salt would reconsolidate and reduce porosity and permeability. As depicted in Figure 3, creep closure and the natural healing mechanisms of crushed salt would tend to eliminate void space. The relatively high mean stresses calculated by Callahan and DeVries (greater than 10 MPa) ensures the granular salt would have porosity less than 5% in a very short time. Based on the permeability/density relationship noted earlier (Sandia, 1996), this range of consolidation equates to a permeability less than or equal to 10^{-18} m^2. Eventually, in a few hundred years, permeability will return to values equivalent to intact salt ($K<10^{-19}$ m^2). These porosity and permeability values are estimated from a body of experimental work supporting the compliance shaft seal design report (Sandia, 1996), and indicate that both permeability and porosity of rooms backfilled with mined salt would become much lower than the value of typical waste rooms. Behavior of rooms left empty would mimic rooms back-filled with crushed salt, because the salt debris is analogous to salt back-fill. The requisite closure for re-consolidation would ensue within decades.

In terms of the performance of the repository over the regulatory period, the permeability of the closed room will be more than several orders of magnitude less than the waste (value for waste permeability in the Compliance Certification Application was 1.7×10^{-13} m^2). Given this wide diversity of permeability, the closed rooms will behave from a performance standpoint as if they represented intact salt. Early in the life of the repository, before the rooms have fully closed, the open rooms will have the potential to act as open conduits, and therefore as preferential pathways for fluid, in the event of a human intrusion. However, when the rooms close in a time on the order of 200 years, as indicated by Morgan's calculations and by mining experience, total closure will occur before likely intrusion. In the CCA model, the first intrusion could not occur until 700 years after WIPP decommissioning, and in the PAVT until 100 years, and in both cases the mean time for the first intrusion was on the order of 1500 to 2000 years. Also, note that even if certain rooms in Panel 1 remain empty, panel closures will still control flow of fluids into and out of the Panels – any high permeability path through an empty room would only effect flow regimes within the Panel. Finally, it should be noted that a fully closed room will not have any remaining channels for flow. The only effect in PA of leaving certain rooms open will therefore be to marginally reduce the waste storage area.

References:

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Mraz, D., L. Rothenburg and J. Unrau. 1996. "Review of In-Situ Stress and Strain Monitoring Programs around Openings in a Deep Potash Mine," Proceedings 4th. Conference on the Mechanical Behavior of Salt, Montreal.

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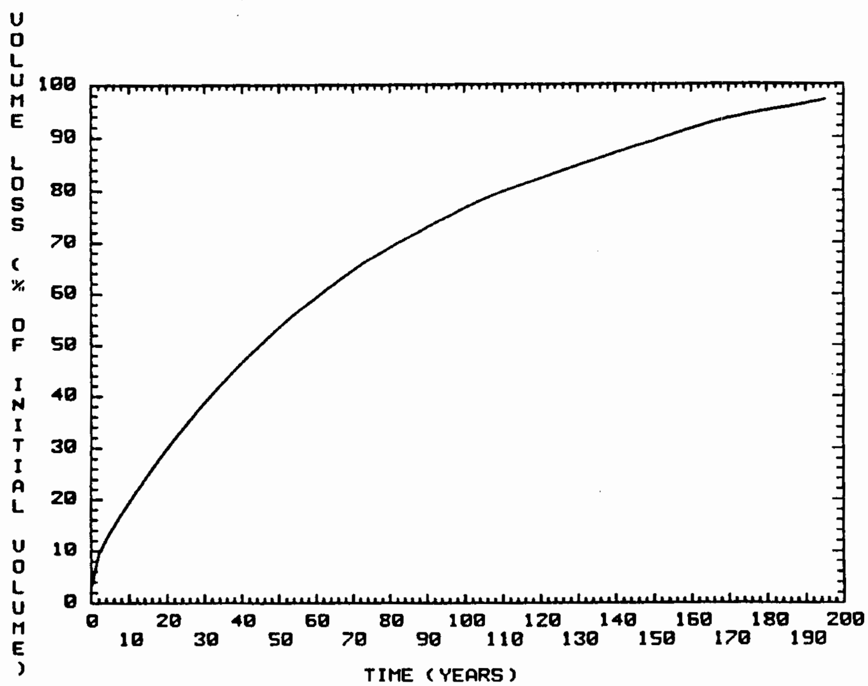

Figure 1. Closure of Empty Storage Room (Morgan, 1987)

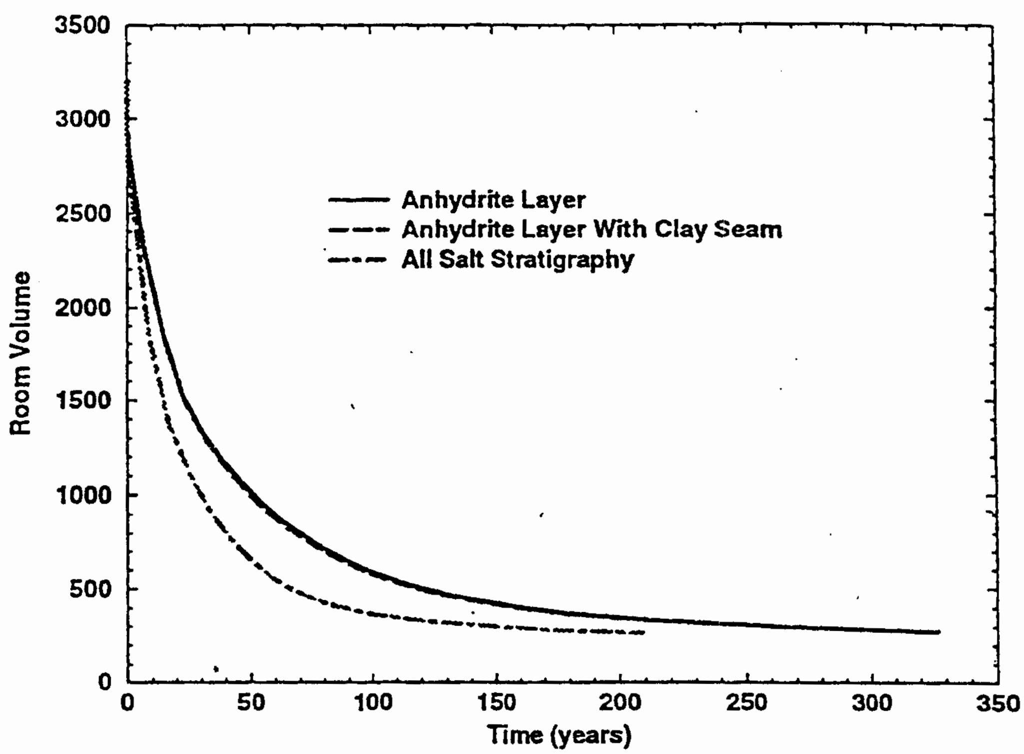

Figure 2. Disposal Room Volume (m^3) Reduction with Time.

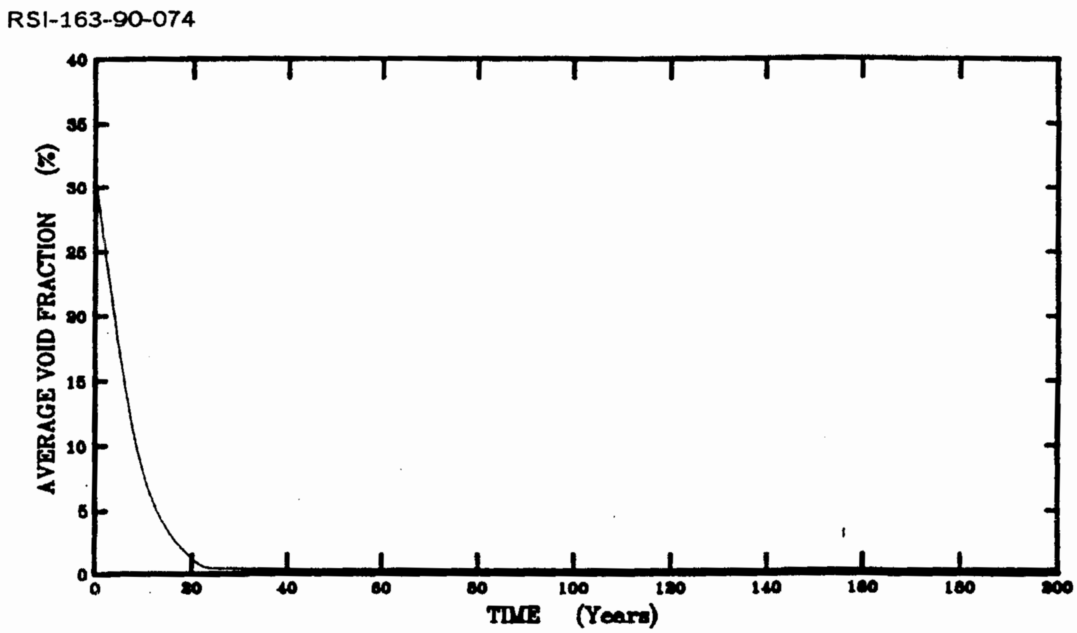

Figure 3. Disposal Room Volume Reduction when Back-filled with Crushed Salt.

4. Waste Loading:

It appears that your conclusion that the expected total releases from the repository are independent of the waste loading scheme is predicated on the assumption that waste is uniformly emplaced. Under the proposed changes, waste will not be uniformly emplaced in Panel 1. Is this conclusion still appropriate? Please explain.

CBFO believes that the conclusion is still appropriate. Attachment IV and Section 3.6 of the DOE submittal on Panel 1 Utilization present detailed analyses and a reasoned argument to demonstrate that the expected release from the repository will be independent of the waste emplacement scheme. It may be helpful to rephrase the assumptions, arguments and reasoning used in the Appendix IV mathematical analyses, since those analyses are rather abstract.

The basis for concluding that the expected total release from the repository is independent of the waste emplacement scheme has two components. First, the mathematical analysis in Attachment IV demonstrates that the expected release from cuttings/cavings is independent of the waste loading scheme. Then, Section 3.6 of the DOE submittal provides a reasoned argument to demonstrate that this result is also applicable to the total release from the repository.

Before discussing each component, it is useful to define the "expected" release from the repository. The expected value is the average or mean value of all the releases from a CCDF, i.e., each point on a CCDF represents a consequence (a release) for a specific time history of borehole intrusions. The average value of all these consequences represents the expected or mean value of the release from the repository. Note that this expected value will be a single value, as opposed to a CCDF that has a range of values for various intrusion time histories.

Mathematical Analysis (Attachment IV)

Attachment IV demonstrates that nonuniform loading of waste within the repository will have no effect on the expected value of the CCDF for cuttings/cavings. This is demonstrated by proving that the expected volume released by cuttings/cavings is independent of the area over which the waste is emplaced and of local variations in the (physical) density of the emplaced waste (see Sections IV.2(a) and IV.2(b)). The mathematical proof for this conclusion is derived in Section IV.2(b). Equation IV.2 of Section IV.2(b) demonstrates that the expected volume is independent of the fraction of the waste, fWD_i, loaded in each separate area of the repository, $aWDi$, and of the total number of separate areas in the repository, nWD, so that the number of panels and rooms is irrelevant to the expected volume released by cuttings/cavings. In fact, the repository can be divided into an arbitrary number of small areas, each with its own unique conditions (e.g., loading), but the expected or average volume released will be the same.

Section IV.3 extends this argument from the expected volume released to the expected activity of the radionuclides released by cuttings/cavings. The expected value of radionuclide release, shown in Equation IV.10, is independent of: the initial areal density, dR_i, of radionuclide in the i^{th} area; the fraction of the total amount of radionuclide, fR_i present in the i^{th} area; and, the total number of separate areas, *nWD*, in the repository. Again, the repository can be divided into an arbitrary number of small areas, each with its own radioactive waste loading without affecting the expected or average activity released.

A key assumption for the derivation in Section IV.3 is that the activity of the waste removed by cuttings/cavings is proportional to the product of the cuttings/cavings area and the areal density in the i_{th} area of the repository. This is certainly true for cuttings/cavings, which is conceptualized to remove a plug of material with all its radionuclides from the repository immediately to the surface.

Reasoned Argument (Section 3.6)

The analysis in Attachment IV is specific to cuttings and cavings, but it can be extrapolated to demonstrate that the expected total release from the repository is independent of the actual waste loading scheme. The reasoned argument is as follows:

- Attachment IV shows that the expected radioactive release through cuttings/cavings is independent of the detailed waste-loading scheme in individual rooms and of the waste loading scheme in smaller areas within each room.

- The analysis in Attachment IV.3 also applies to the expected releases of CH-TRU through spallings, if 1) the spall volume is unchanged by the waste loading scheme and 2) the activity of the released material varies linearly with the fraction of waste activity emplaced in each room. The first condition is consistent with the CCA, wherein spall volume depends on the physical properties of the waste but is independent of the radioactive content. The second condition is also reasonable because an area with (for example) one-half of the nominal complement of radionuclides will generally release one-half of the activity that an area with the nominal complement of radionuclides will release.

- Cuttings/cavings and spallings are the main components of the total expected release from the repository (see Figure 13.2.3, Helton et al. 1998). Since the expected releases from cuttings/cavings and spallings are independent of the waste loading scheme, and since the total release is essentially the sum of the releases from cuttings/cavings and spallings, it follows that the total expected release will also be independent of the actual waste loading scheme.

Reference:

Helton, J.C., J.E. Bean, J.W. Berglund, F.J. Davis, K. Economy, J.W. Garner, J.D. Johnson, R.J. MacKinnon, J. Miller, D. G. O'Brien, J. L. Ramsey, J.D. Schreiber, A. Shinta, L. N. Smith, D.M. Stoelzel, C. Stockman, and P. Vaughn. 1998. *Uncertainty and Sensitivity Analysis Results Obtained in the 1996 Performance Assessment for the Waste Isolation Pilot Plant.* SAND98-0365. Albuquerque, NM: Sandia National Laboratories.