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A Revisit of Waste Shear Strength

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Executive Summary

This paper examines waste shear strength, which is a parameter required for the CUTTINGS_S code used in Waste Isolation Pilot Plant (WIPP) performance assessment. The values used for this parameter are extraordinarily low and without justification. Examination of the documentation for this parameter shows that there is no connection between the values implemented in WIPP performance assessment and the expected evolution of the underground based on known features, events and processes. Calculated release volumes from human intrusion models are important contributors to overall compliance determination. Scientific diligence is essential both in consideration of waste shear strength and consistency with the conceptual model to which it is applied. Evaluations show that if waste shear strength is treated conservatively, but consistent with available knowledge, cavings releases will be significantly reduced.

To address the issue of waste shear strength, a review is made of documents in the record supporting the compliance certification application (CCA) and subsequent calculations. For the most part, the documents that report values for waste shear strength include neither a justification for the waste shear strength nor a model explaining how the waste evolves. These shear strength values are too low to be credible. More appropriate limiting values for waste shear strength and a concept from whence they derive are given in this paper. These values include quantitative results of laboratory flume experiments as well as a qualitative reflection on the expected evolution of disposal rooms.

Simulations using the cavings model show the sensitivity to critical shear strength: cavings quantities are realized only when the sampled shear strength becomes vanishingly low. The most likely future state of a disposal room includes compacted and cemented waste, with physical and mechanical characteristics that include high shear strength. A more appropriate range for waste shear strength is limited at the minimum by an extremely low strength representing comprehensive degradation. At the higher end of the distribution function shear strength is set equal to the tensile strength of salt, which is precipitated by brine consumption. The higher shear strength values are of no consequence in terms of the compliance modeling effort because modest shear strength eliminates cavings into the wellbore. For scientific credibility, it is important to capture the lowest shear strength in a conservative and justifiable manner consistent with knowledge of the underground setting.

The first section of this paper summarizes what is in the compliance record regarding waste shear strength. The second section reflects upon what the shear strength should be. The third section shows the impact shear strength increase would have on the process model for cavings. An appropriate range of shear strength with a conservative lower limit will essentially eliminate cavings as a release mechanism in performance

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assessment. The fourth section outlines a realistic evolution of the WIPP underground and a general plan forward.

1.0 The record regarding waste shear strength

The WIPP is a robust repository for the nation's transuranic waste. Its ability to isolate waste and meet regulatory requirements is evaluated via computer models, which have been extensively scrutinized. The technical viability of the models and input parameters are constantly evaluated as information is gained and the technical basis advanced. Part of the analyses that demonstrate regulatory compliance involves drilling intrusion into the repository. Properties of the waste become important when releases to the wellbore are calculated. One of these properties is waste shear strength, for which extremely low values have been used.

The CCA (DOE, 1996, Section TRU.2.5.2.) provides descriptions of the physical properties of the solid waste components used in performance assessment. The primary properties are listed in Table 1.

Table 1. Parameter Values[1] for Performance Assessment Calculations.

Parameter	CCA	PAVT	CRA Submittal
Tensile Strength	0.0069 MPa	0.0069 MPa	0.12 to 0.17 MPa
Shear Strength	0.05 to 10 Pa	0.05 to 77 Pa	0.05 to 77 Pa
Permeability	$1.7(10^{-13})\ m^2$	$2.4(10^{-13})\ m^2$	$2.4(10^{-13})\ m^2$

[1] Many interested readers may not have a perception of magnitudes expressed in pascals and megapascals (Pa and MPa). The lowest shear strength of 0.05 Pa equals 7 millionths of a pound per square inch (psi) and the highest shear strength of 77 Pa = 0.011 psi. Further perspective will be brought to these values later in this paper.

Waste placed in WIPP is sealed in a variety of containers, which would require comprehensive degradation before the strength of the compacted composite material would be low enough to be evacuated up a hypothetical drill string. Waste strength is only of consequence, and therefore of concern, in the highly degraded state. Strength properties enter directly into performance assessment human intrusion scenarios, whereby a driller inadvertently intersects a repository room. The drill bit and drilling fluid circulate in the advancing wellbore and set up fluid shear stress in the degraded waste. The direct cuttings removal of waste equals a vertical cylinder of the wellbore without an associated waste strength criterion, whereas, caving into the wellbore requires low waste shear strength. In addition, if high pressures exist in the disposal room and the waste has very low tensile strength, a pressure gradient pulse is postulated to induce tensile failure and transport of waste particulate into the wellbore. Therefore, shear and tensile strength are important parameters in the models for cavings and spallings releases

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and both strength properties require massive degradation to reduce the inherent strength of waste containers.

The concepts of cuttings, cavings and spalling releases from human drilling intrusion are summarized by Vugrin (2005). The code CUTTINGS_S calculates the volume of the cylinder of cuttings and cavings removed for a set of vectors, drilling intrusion scenarios, times, and locations. Cuttings and cavings are the solid material removed from the repository and carried to the surface by the drilling fluid during the process of drilling a borehole. Cuttings are the materials removed directly by the drill bit, and cavings are the materials eroded from the walls of the borehole by shear stresses from the circulating drill fluid. Cavings is the eroded material beyond the bit circumference that grows until the shear stress on the borehole wall is equal to the shear strength of the waste.

The shear strength implemented in performance assessment is used to calculate the volume of cavings, hence, it is a measure of erosional shear resistance. In the CCA (DOE, 1996), the waste shear strength was sampled from a uniform distribution from 0.05 to 10 Pa, which is noted in the record as conservatively based on properties of marine clays as a "worst case" in the CCA (Table MASS-1). In preparation of this paper, the original sources of these shear strength values were reviewed (Berglund, 1996; Partheniades and Paaswell, 1970). The Berglund memorandum simply reports the range and cites Partheniades and Paaswell, who provided a review of soil erodibility in channels. It is essential to understand that the review by Partheniades and Paaswell concerned erosion and deposition of mud in channels. They measured erosion rates of San Francisco Bay mud to study the deposition of suspended fine sediment at different velocities. Berglund simply expropriated the values for bay mud and reported them in his memorandum (1996) as if they had some relationship to WIPP waste. Berglund further attributed a uniform sampling distribution in his memorandum on required parameters for CUTTINGS_S in WIPP performance assessment.

A series of activities related to shear strength and cavings was undertaken. In 1997, the EPA directed the DOE to perform studies including a performance assessment verification test (PAVT) (EPA, 1997a) and to convene a panel to determine particle size by expert judgment (EPA, 1997b). In preparation for the PAVT), the waste shear strength was estimated based on particle size distribution determined by an expert elicitation panel (CTAC, 1997). Again the inherent conceptual model was erosion of particulate material. Using the particle size deduced from expert elicitation, the calculated critical shear strength ranged from 0.64 to 77 Pa. Nonetheless, the EPA requested that DOE retain the original lowest value of 0.05 Pa for the PAVT instead of the 0.64 Pa determined via expert elicitation and assigned a log-uniform distribution ranging from 0.05 to77 Pa.

> "Based on information provided to EPA subsequent to the April 25, 1997 letter, the Agency has determined that it is appropriate to use the CCA value for the lower bound of the TAUFAIL parameter. In addition, the results of the expert panel on particle diameter should be used for creating and applying the remainder of

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> the TAUFAIL distribution as indicated in the April 25 letter."
> (EPA, 1997c).

Despite the extensive deliberation regarding particle size, no critical review was undertaken to explain how the containers of waste might devolve into particulate.

Other project work related to human drilling intrusion critically evaluated the conceptual model for spalling. The conceptual model for spall in the CCA had been determined inadequate by the conceptual model peer review panel (Conceptual Model Peer Review Panel, 1996). A team was assembled to develop a mechanistic spall model. One of the more vexing issues involved waste strength, particularly the lowest possible strength conditions of the waste after massive corrosion and microbial consumption. A surrogate degraded waste material was developed and justified by Hansen and others (Hansen et al., 1997; 2003). This material was tested extensively for mechanical strength, and a few samples were tested for hydrodynamic shear strength.

Based on flume experiments of Jepsen et al. (1998, WPO 52647) the lower value of 0.05 Pa was found to be unrealistically low. The surrogate waste samples themselves represented comprehensive degradation without the obvious strengthening associated with MgO hydration and secondary mineral precipitation. Jepsen et al. measured average critical shear strength of 1.4 Pa by subjecting an unconfined cylinder of surrogate to a flume of flowing water. The experimental value measured by Jepsen and others is about twice as large as the minimum deduced from particle size elicitation. The minimal critical shear strength could approach this measured value only if WIPP waste were massively decomposed. Jepsen's samples represented an unobtainable degraded state and are thus far weaker than any possible future state of the waste. Even so, this extremely weak material yielded erosional shear strength 30 times larger than the minimum value used in current analyses. The minimum erosional shear stress determined by Jepsen does however, have a logical though extremely conservative connection to the WIPP waste decomposition. For these reasons and based on the record supporting the compliance determination, it appears that the lower ranges of waste shear strength are without basis while more appropriate and still ultraconservative values have been developed.

2.0 What the waste shear strength should be

There are several aspects of the unfathomably low shear strength that are inconsistent with known facts. The inconsistencies will be discussed in this section, which includes more reasonable, yet conservative approaches to waste shear strength. Scientific credibility requires consistency with respect to features, events, and processes. It is not sufficient or appropriate to select or use unjustifiable shear strength values because they are conservatively low.

The value for waste shear strength has been noted "conservative" and "worst case" since the process model was introduced (Table MASS-1 of the CCA). Section 1 acknowledges that the range of values sampled for shear strength of San Francisco Bay mud as a surrogate for the future state of the waste lacks any logical or scientific basis. Information available in the record regarding waste shear strength apparently has been ignored and

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performance assessment parameters are not consistent with the knowledge and information available. The general issue regarding waste shear includes several related, but pertinent technical issues regarding the conceptual model and consistency. If we step back and examine the features, events and processes expected to control the future states of the WIPP waste inventory, a much more defensible model arises and the waste shear strength increases beyond that of bay mud.

First, it is important to review the concept of shear strength. Erosion, scouring, and deposition studies of soil in channels implement the concept of critical shear stress. This is an erosional resistance parameter. It should be noted that the critical shear stresses are smaller by orders of magnitude than the macroscopic soil shear strength (Partheniades and Paaswell, 1970). It is informative to review these values and testing techniques in the context of WIPP waste shear strength. The <u>mechanical shear</u> tests are well known—such as direct shear and triaxial compression in the laboratory setting and the vane shear test in situ. These tests measure a shear strength whereby the material loses strength because shear planes of failure are imparted to the specimen. By contrast, the critical shear stress measurement is hydrodynamic, where flowing water loosens the outer most layer and erodes or carries it away. Flowing water across the surface of the compacted mass applies the <u>hydrodynamic shear stress</u> (which is calculated). The critical shear stress is the applied hydrodynamic shear stress at which the material just begins to erode.

The applied shear stress within the flume depends on the size of pump used to produce the flow (maximum flow rate) and the dimension of the flume channel cross-section. The system at University of California Santa Barbara (UCSB) (Jepsen et al., 1998; McNeil et al., 1996)) could create shear stresses on the order of 10 Pa (+/- 2 Pa) depending on the set-up. Flume devices may be capable to developing 15 Pa or so, and most sediment erodes readily at shear stresses of this magnitude. The important point here is that the test technique for critical shear stress measures hydrodynamic mobilization of the layers of fine-grained soils. This would be an appropriate test for fine grained mud, but it is inconsistent with the expected state of the waste—even severely decomposed waste, which would be cemented with hydrated MgO, salt precipitate and secondary minerals (Hansen and Stein, 2005). Thus, the shear strength values used in performance assessment are misleading as well as inconsistent with WIPP waste evolution.

The evolution of the waste rooms has been re-visited recently (Hansen and Stein, 2005). The waste room inventory certainly will not transform into the equivalent of bay mud, as the shear strength model stands today. There never has been a model put forward for the transformation of the waste containers and their inventory into oozing particulate matter. There is no scientific foundation for selection of these incredibly low shear strength values. However, there has been a logical, systematic, albeit very extreme case put forward from which minimal hydrodynamic critical shear stress can be realized (Hansen et al., 1997; Jepsen et al., 1998).

The probability distribution function for waste shear strength might include the low, but finite value obtained by Jepsen and co-workers (1.4 Pa) as a legitimate "worst case". This value is based on logical, but extreme degradation, and flume testing. These tests

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provide a minimal stress for erosion of the outer layer of particles on a weak surrogate for highly degraded waste. The range offered by Berglund (1996) for performance assessment is below the lowest values measured for the most severe waste degradation. Based on the best information available, an empirical minimal shear strength value is 1.4 Pa. This extremely low value stretches credibility, but allows establishment of the lowest limit of a probability distribution function for erosional shear strength. The nominal shear strength is much greater than the lowest values sampled in today's performance assessment.

Several features, events and processes in the disposal room can be modeled more accurately than currently implemented in the performance assessment. When these existing facts are incorporated into waste room evolution, a vastly different picture emerges including a waste much stronger than currently modeled.

Degraded material property estimates were developed for an estimated inventory stored in standard 55-gallon drums. The standard 55-gallon drums are the most compliant waste containers brought to WIPP, some of which can be seen in the photograph in Figure 1. Wastes now coming to WIPP include super-compacted pucks, stainless steel pipe over packs and ten drum over packs. It is logical to conclude that super-compacted pucks residing inside 100-gallon drums might degrade less rapidly or less completely than the single-shell 55-gallon drums. Likewise, the ten drum over pack comprises drums within drums, both providing resistance to degradation and providing a substantial structural column. Degraded material property estimates were recently summarized for the spallings model peer review (Hansen et al., 2003). The authors assert that degraded waste properties determined for the spall model, DRSPALL, represent the lowest plausible realm of the future possible states of the waste because strengthening processes are not included in the minimal cohesion and tensile strength properties determined for surrogate degraded waste. More durable waste packages are less vulnerable to collapse and more resistant to massive corrosion. Presence of robust waste packages and a more correct evolution of the underground as espoused by Hansen and Stein (2005) give rise to a room environment greatly different than one comprising bay mud. The physical and mechanical properties of the future state of the waste would certainly include high shear strength.

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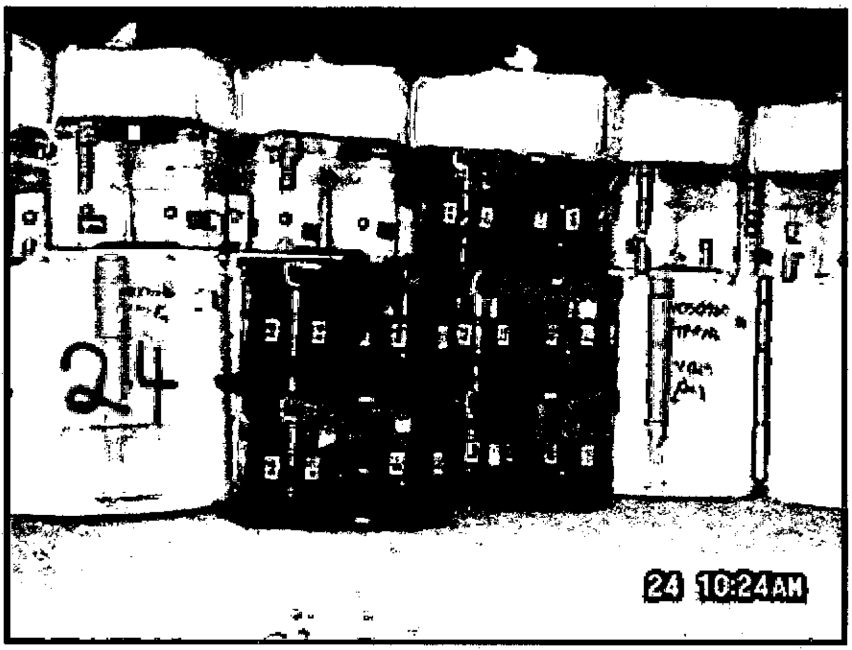

Figure 1. Photograph of waste at WIPP (Courtesy of Steve Casey)

Generally speaking, physical and mechanical properties are related. A material possessing high compressive strength also has a high shear strength and tensile strength. Of course relative strength often depends on such properties and characteristics as elasticity, plasticity, brittleness, continuity, homogeneity, morphology, and so on. Steel has approximately the same strength in tension and compression, while rocks generally have a tensile strength about one tenth of the uniaxial compressive strength. The shear strength of pressure sensitive geomaterials is roughly half of the compressive strength. These concepts of consistency concerning the nature of material properties are very important to understand just how minute the shear strength values currently assigned to the waste are.

As an example, in the CCA/PAVT a tensile strength of 1 psi was assigned for the tensile strength of the waste. No justification was provided for this extremely low value and hence it is without foundation. Tensile strength of 1 psi is nearly impossible to measure by conventional geomechanics laboratory techniques because a sample of such material will fall apart in your hand. Damp beach sand might have a tensile strength of 1 psi. Again generally speaking, mechanical shear strength is greater than tensile strength, but for purposes of discussion let us assume the waste shear strength is equal to the untenable tensile strength of 1 psi (1 psi = 6,900 Pa). The lower end of the shear strength distribution function used in the CCA/PAVT is 0.05 Pa, approximately 140,000 times <u>weaker</u> than the shear strength of damp sand.

Experimental work by Hansen and co-workers (1997; 2003) established a possible lowest tensile strength value based on inventory, evolution and experimental determination. Experimental work on comprehensively degraded WIPP surrogate waste provides results indicating that the lowest tensile strength for this extreme surrogate ranges from 0.12 to

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0.17 MPa. Therefore, a more correct and justifiable lowest value for tensile strength is approximately 20 psi. As one follows the logic regarding strength, it becomes apparent that values sampled for shear strength in the performance assessment are too low by orders of magnitude.

The Conceptual Model Peer Review Panel (1996) acknowledged the assumption that the effective shear resistance to erosion of the repository waste is similar to ocean bay mud. They stated that in the absence of experimental data, the absence of accurate waste characterization, or knowledge of the form of this waste at the time of intrusion, this assumption appears appropriate because of the low shear strength. However, experimental data developed since then produced a value for minimal hydrodynamic shear strength (1.4 Pa). Thus, experimental data exist for the worst case degradation and the lowest strength. The conceptual model implied by this representation of waste shear strength however, is not correct and can be made more technically acceptable. Use of the hydrodynamic critical shear stress is consistent with a model whereby the waste shown in Figure 1 is transmogrified into fine grained, oozing particulate matter.

A more scientifically sound evolutionary track has been put forward by Hansen and Stein (2005). There are no processes imagined or proposed that can comminute and unconsolidate the waste, because known features, events and processes lead to a future state of compressed and relatively intact waste packages, encased at the base with hydrated MgO if any brine actually finds its way to the waste room. The sampled uncertainty range in shear strength must include the inherent strength of the waste packages as well as the extremely degraded worst case. The probability of intruding into unconsolidated, cohesionless, particulate waste is vanishingly remote and should represent the limit of the shear strength in the distribution.

What, then, is a reasonable value for the higher waste shear strength of the probability distribution? Based on a defensible evolution, as described by Hansen and Stein (2005), and allowing that degradation necessitates the consumption of brine, waste solids would be sutured with sodium chloride crystallites, hydrated MgO and secondary minerals from corrosion. A conservative composite strength might be reasonably set to the tensile strength of salt, which is 1.4 MPa (Hansen et al., 1984).

3.0 Impact of Shear Strength Increase on PA

There are two parts to address the impact of waste shear strength on performance assessment. The first impact is a demonstration that very modest increases in the waste shear strength eliminates caving into the wellbore. The second impact derives from the acknowledgement that the waste shear strength has a much greater probability of being high than low. The first example obtains the cavings model output from performance assessment and simply evaluates the cavings volumes as a function of waste shear strength. Sensitivity analyses determined that uncertainty in shear strength was significant in the performance assessment results (Helton et al., 1998).

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Vugrin (2005) recently ran an analysis termed the 2004 CRA Performance Assessment Baseline Calculation (CRA-2004 PABC). In these analyses he sampled the effective shear strength (BOREHOLE:TAUFAIL) and the drill string angular velocity (BOREHOLE:DOMEGA). As can be in Table 2, he implemented the extremely low range of hydrodynamic shear strength used in the CCA, PAVT and the Compliance Recertification Application (CRA).

Table 2. Sampled Uncertain Parameters for Cavings Calculations

Material	Property	Distribution	Range	Description
BOREHOLE	TAUFAIL	Loguniform	0.05 to 77.0 Pa	Effective shear strength for erosion of the waste
BOREHOLE	DOMEGA	Empirical Cumulative	4.2 to 23.0 rad/s	Drill string angular velocity

Vugrin's results are presented in Figure 2 which is a semilog plot showing that lower shear strengths lead to larger cavings volumes. This observation agrees with the cavings model because the shear strength of the material is the limiting shear stress below which the erosion of the waste ceases. Shear strength clearly dominates cavings and as the shear strength approaches approximately 10 Pa, cavings diminish toward zero.

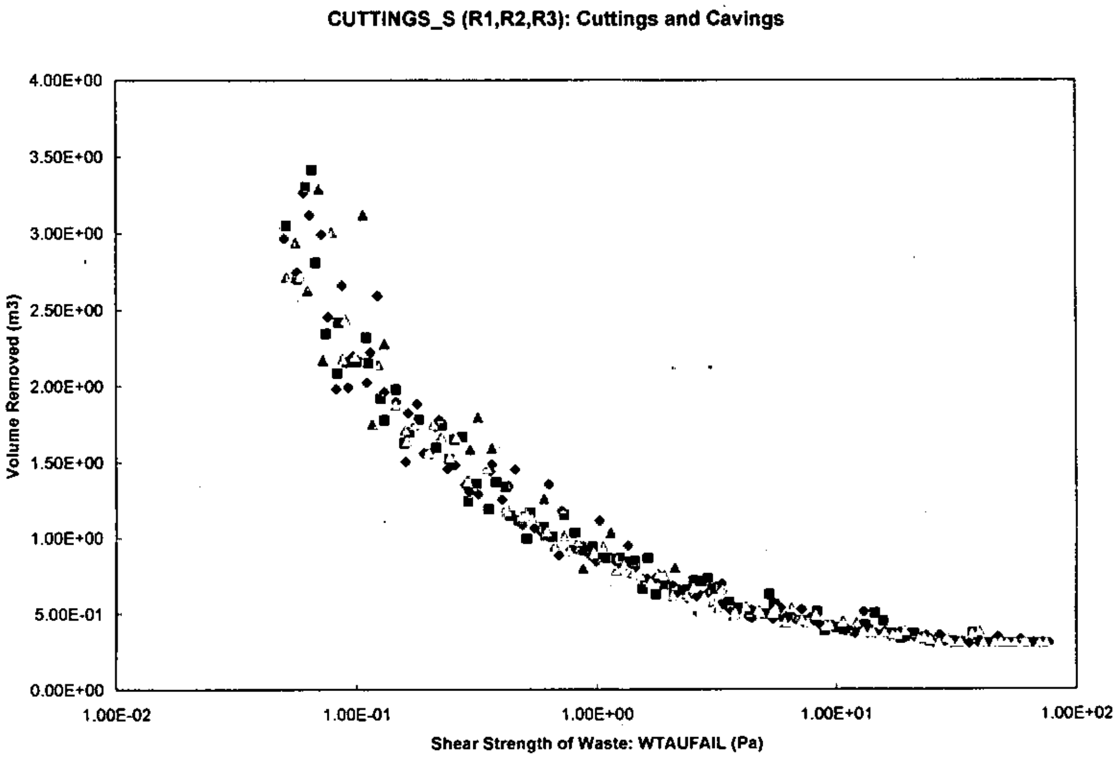

Figure 2. Scatterplot of Cuttings & Cavings Releases versus Shear Strength (After Vugrin, 2005).

Figure 3 is a scanned image of the CUTTINGS_S releases as calculated for the CCA (Helton et al., 1998; Figure 9.1.3). One can readily observe that calculations run for the CCA are essentially the same as those more recently calculated by Vugrin. The volume

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released through the cavings mechanism increase as the shear strength approaches zero. When the shear strength approaches 10 Pa the cavings mechanism produces no releases. The crucial point here is: for the process model implemented in CUTTINGS_S the shear strength of the waste must be exceedingly low for the model to produce cavings. When the waste shear strength approaches 10 Pa (0.0015 psi), calculated erosion into the wellbore approaches zero.

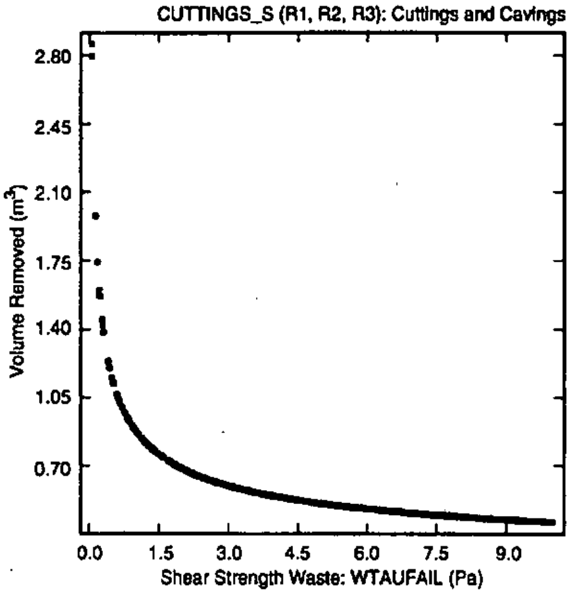

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Figure 3. Plot of Cuttings and Cavings Volumes versus Shear Strength

As noted previously, it is important to have a cognitive sense of what 10 Pa (0.0015 psi) shear strength represents. Recall that 1 psi represents a material, such as wet sand, that is difficult to test because it disaggregates in your hand. The waste shear strength at which calculations show there is no cavings is 0.0015 psi, roughly 100 times weaker than wet beach sand. To create cavings, the original barrels, boxes and over packs of waste must degrade to something that is 100 times more erodible than wet sand. No basis or credible evolution has ever been established for such low shear strength. By contrast the experimental minimum of 1.4 Pa has been measured on surrogate material created to represent an unapproachably weak condition of the waste. And a technical basis has been established for this hydrodynamic shear value. As shown in Figures 2 and 3 above, even the extremely low shear strength of 1.4 Pa greatly limits caving into the wellbore.

It is clear from the above discussion that waste shear strength--in actuality--is far higher than the range of values sampled for performance assessment. The range of shear strength currently sampled cannot be justified. However, it is possible to quantify the shear strength parameter in a more scientifically rigorous manner, as cited in this paper. Using the current model and a more credible and justified range of shear strength, caving releases to the borehole would be minimal. It is important to realize that the expected evolution of the underground includes reasonable expectation and consistent interpretation of the features, events and processes involved with the human intrusion

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scenario. The possible ramifications to performance assessment of a more realistic evolution will be outlined next.

4.0 Plan Forward with a more appropriate model

A performance assessment is meant to capture features, events and processes of the underground setting. Brine is essential for corrosion and microbial consumption of the waste. Several conditions of the disposal environment lead to the conclusion (Hansen and Stein, 2005) that no free brine will be available and, in fact, the room will be desiccated by an overwhelming inventory of MgO. A dry repository means that the waste is neither chemically nor biologically degraded as the surrounding Salado salt compresses the waste stack. The structural response of robust waste packaging is a key to the future state of the waste. To the extent that this memorandum is for the purpose of reducing uncertainty in the waste shear strength as currently implemented, the shear strength will undoubtedly be orders of magnitude greater than values sampled in the current performance assessment. Shear strength will be so substantial that cavings into the wellbore will not occur using the current conceptual model. In fact, it would be exceptionally difficult to penetrate the compacted waste using conventional drilling practices.

The discussion of waste shear strength illuminates several areas in which the current conceptual model for WIPP disposal room evolution is at odds with project knowledge, experience and expectations. Changes to an alternative evolution including a change in shear strength may require corroboration by peer review.

A room full of stiff and robust waste packages will be held open (i.e., the waste would prevent salt creep from closing the room) to a greater extent than by standard waste packages. The more rigid waste packages would tend to maintain the open channels between individual drums and packages. Thus, more of the original porosity inherent in the three-dimensional disposal configuration would be preserved. Results from finite element models (Park and Hansen, 2003a, 2003b) show that the stiffer wastes provide greater resistance to room closure than the standard drums. Examples of these results are shown in Figure 4, all plots for the (appropriate) case in which no gas is generated. The current conceptual model for standard waste is more deformable than other packaging and reflects maximal room closure.

Room porosity in the absence of gas generation remains higher for rooms full of robust waste forms, such as AMW packages, than for rooms full of standard waste. There are many details associated with theses types of models, which will require additional analyses. The point here is to showcase global concepts as a more relevant disposal room evolution is developed for WIPP. The structural response shows that stiffer waste influences creep closure of the room by providing a "rigid-pillar" effect. The rapid closure prevailing in the first decade will be slowed appreciably before the void space in the room is closed. Therefore, the porosity in a room containing rigid waste packages will be greater than the porosity of a room containing standard wastes in 55-gallon drums.

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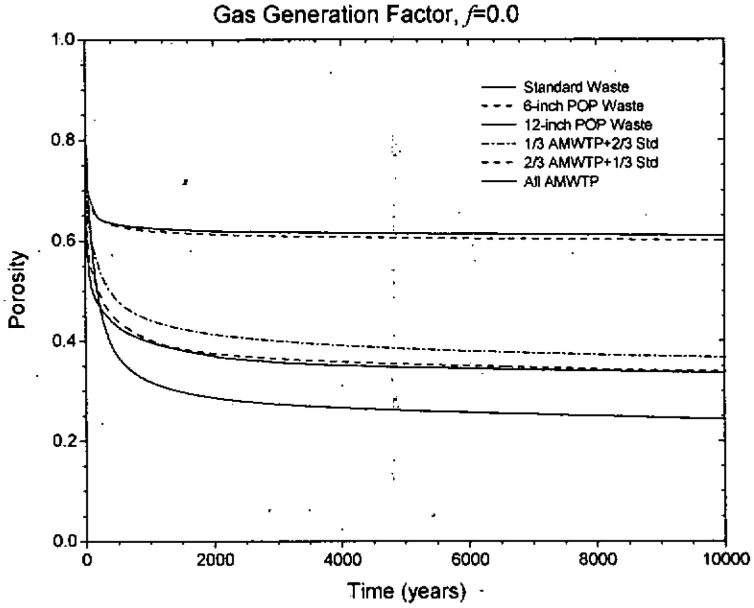

Figure 4. Comparison between porosity histories for the disposal room containing various wastes. AMWTP is advanced mixed waste treatment process. POP is pipe overpack.

This phenomenon can be explained with a simple Kelvin model of a spring and a dash pot in parallel. The spring analog represents the stiff waste taking on load and the dash pot represents the salt pillar that loses load to the waste stack. In this case the waste will absorb or redistribute vertical stress from the salt pillars onto itself. The rate of vertical stress increase in the waste is proportional to its elastic deformation, while the deformation of the softer salt pillar is limited by the deformation of the waste. It appears as if the pillar sheds its vertical stress because any elastic rebound is completely overshadowed by the previous and contemporary creep shortening. Eventually new stress equilibrium is reached where the salt pillar adjacent the waste no longer shortens by creep because the waste now carries the vertical stress that was causing the salt to creep. The rigid materials comprise particular inventories of waste, which act to crib the rooms open. Simultaneous with load uptake in the waste stack, stress in the pillars between rooms tends to decrease, and vertical room closure is restricted due to the decrease in the stress differences that give rise to creep deformation. Lateral deformation of the rooms also decreases appreciably when rigid materials are placed within them.

The expected future of a WIPP disposal room has been outlined by Hansen and Stein (2005) based on the best information available to the project. There are several features, events and processes that can be reflected more appropriately and there are some elements of the rooms, MgO for example, that have acknowledged first-order impact on the physical, mechanical and chemical setting if brine is available. The rigidity of packages such as the pipe overpack and supercompacted waste pucks tends to hold the room open and preserve the structural integrity of the waste stack. The logical evolution involved with disposal of a more rigid and armored waste package would be preservation

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of a large portion of the waste in a compacted but intact form as it will deform rather less than standard waste packages. Thus, the architecture of the waste comprises bulky, compressed steel containers that envelop the waste. The rigid structure would tend to maintain the open channels between individual drums and packages, allowing the MgO to fall into the interstices between the waste columns.

A much drier evolution than currently modeled should be the baseline for performance assessment. Alternatives to a completely dry evolution could include an intermediate case in which some amount of brine enters the room and hydrates some of the MgO. A dry repository model will prevail until human intrusion introduces brine into the remaining voids. Future performance assessment process models need to be re-examined with an emphasis on defensible evolution of the disposal rooms supported by the knowledge and experience gained to date.

References

Berglund, J. W. 1996. Parameters required for the CUTTING_S code for use in WIPP Performance Assessment. ERMS#236766.

CTAC. 1997. *Expert Elicitation on WIPP Waste Particle Diameter Size Distribution(s) during the 10,000-Year Regulatory Post-closure Period: Final Report* U.S. Department of Energy Carlsbad Area Office. Carlsbad, NM.

Conceptual Model Peer Review Panel. 1996. Conceptual Models Peer Review Report. Prepared for the U.S. Department of Energy.

DOE (U.S. Department of Energy.) 1996. Title 40 CFR Part 191 Compliance Certification Application for the Waste Isolation Pilot Plant. DOE/CAO-1996-2184. October 1996.

Environmental Protection Agency (EPA) 1997a. EPA Letter from E.R. Trovato, Office of Indoor Air, to G. Dials, Manager of Carlsbad Area Office regarding parameters to be used in a performance assessment verification test, EPA docket A-93-02, II-I-25, April 17, 1997.

Environmental Protection Agency (EPA) 1997b. EPA Letter from E.R. Trovato, Office of Indoor Air, to G. Dials, Manager of Carlsbad Area Office regarding particle size parameter requiring Expert Judgment, EPA docket A-93-02, II-I-27, April 27, 1997.

Environmental Protection Agency (EPA) 1997c. EPA Letter from M. Kruger, Office of Indoor Air, to G. Dials, Manager of Carlsbad Area Office regarding Performance Assessment Parameter Values Identified in EPA Letters Dated April 17 and 25, 1997, to DOE, EPA docket A-93-02, II-I-33, June 6, 1997.

Information Only

Hansen, F. D., K. D. Mellegard and P.E. Senseny. 1984. Elasticity and Strength of Ten Natural Rock Salts. Mechanical Behavior of Salt, Proceedings of the First Conference. Trans Tech Publications, Clausthal-Zellerfeld, Germany.

Hansen, F. D. and J. S. Stein. 2005. WIPP Room Evolution and Performance Assessment Implications. Sandia National Laboratories. Albuquerque, NM. ERMS #538870.

Hansen, F.D., M.K. Knowles, T.W. Thompson, M. Gross, J.D. McLennan and J.F. Schatz. 1997. *Description and Evaluation of a Mechanistically Based Conceptual Model for Spall*. SAND97-1369. Sandia National Laboratories. Albuquerque, NM.

Hansen, F.D., T.W. Pfeifle, and D.L. Lord. 2003. SAND2003-2930. *Parameters Justification Report for DRSPALL*. Sandia National Laboratories. Albuquerque, NM. ERMS 531057.

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

Jepsen, R., J. Roberts, and W. Lick. 1998. *Development and Testing of Waste Surrogate Materials for Critical Shear Stress*. Sandia National Laboratories. Albuquerque, NM. ERMS #533809.

McNeil, J., C. Taylor and W. Lick. 1996. Measurements of the Erosion of Undisturbed Bottom Sediments with Depth. Journal of Hydraulic Engineering, Vol. 122, No. 6.

Park, B.Y. and F. D. Hansen. 2003a. *Simulations of the Pipe Overpack to Compute Constitutive Model Parameters*. Sandia National Laboratories, Albuquerque, NM. ERMS# 533188.

Park, B.Y. and F.D. Hansen. 2003b. *Determination of the Porosity Surfaces of the Disposal Room Containing Various Waste Inventories for the WIPP PA*. Sandia National Laboratories. Albuquerque, NM. ERMS# 533216

Partheniades, E. and R. E. Paaswell. 1970. Erodibility of Channels with Cohesive Boundary. Journal of the Hydraulics Division. Proceedings of the American Society of Civil Engineers. Vol. 96. No.HY3.

Vugrin, E. D. 2005. Analysis Package for CUTTINGS_S: CRA-2004 Performance Assessment Baseline Calculation. Sandia National Laboratories. Carlsbad, NM. ERMS# 540468.

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