SAND2018-1403C

Answers to Specific EPA Questions

EPA/DOE Technical Exchange

February 2018

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC., a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525
This research is funded by WIPP programs administered by the Office of Environmental Management (EM) of the U.S. Department of Energy.

A.2.a. Overarching Questions

1. Based on EPA's review of available data and modeling we expect all non-waste areas, including the panel closures, will creep close to WIPP like salt properties (i.e., very low porosity and permeability) within a few hundred years post excavation raised in **Issue 24**. What is DOE's understanding of the creep closure processes and end state properties of the salt in the open areas, including unfilled access drifts? Please explain.

RESPONSE

DOE's understanding of the creep closure processes is summarized in the DOE/EPA Technical Exchange presentation, "Overview of Open Room Closure." End state properties of the salt in open areas for CRA-2019 will be unchanged from CRA-2014 parameters. The bases for porosity and permeability values are provided on the following slides. DOE continues to investigate end state properties of the salt in open areas as described in the DOE/EPA Technical Exchange presentation, "Ongoing Research Related to Open Room Closure," which will support parameter assessments for CRA-2024.

Porosity: Panel Closures and Non-Waste Drifts

Material	Value (--)	Analyses	Explanation
Operations Area	0.18	AP129-APCS	Value from porosity surface after 10,000 yrs assuming 8 MPa. Taken as a constant because it was shown to be unimpactful for repository performance. (ERMS 232281)
Experimental Area	0.18	AP129-APCS	Value from porosity surface after 10,000 yrs assuming 8 MPa. Taken as a constant because it was shown to be unimpactful for repository performance. (ERMS 232281)
Removed Panel Closures	0.18	APCS	Taken to mimic the operational and experimental areas, using the same logic and additional sensitivity tests showing high values are conservative for repository performance.
Panel closures early times	0.27	AP129	Initial analyses set porosity to 0.27 to represent the volume average of uncompressed granulated salt (n=0.33) and an explosion wall (n= 0.05).
	Uniform dist. 0.066-0.187	**CRA14BL, SEN4, APCS**	**Current values were derived from 50-year JAS3D simulations of crushed salt compression starting with a range of initial porosities.**
	0.01	CRA14_SEN3	CRA14-SEN3 tested extremely low porosities representative of the minimum value of undisturbed halite for the duration of the model.
Panel closures transitional times	0.05	AP129 – PC3R	Numerical simulations by Callahan and DeVries (1991) estimate salt reaches 0.05 porosity in less than 100 yrs.
	Uniform dist. 0.025-0.075	**CRA14BL-APCS**	**Current values were updated with JAS3D simulations to include a broader range of initial salt porosities to produce the uniform range.**
Panel closures, late times	Uniform dist. 0.01-0.0519	CRA14BL-APCS	Values were derived from 150-year JAS3D simulations of crushed salt compression with a range of initial porosities.

Permeability: Panel Closures and Non-Waste Drifts

Material	Value (log[m_2])	Analyses	Explanation
Operations Area	-11	AP129-APCS	Assumed high value to maximize brine flow into the waste regions. (ERMS 232281)
Experimental Area	-11	AP129-APCS	Assumed high value to maximize brine flow into the waste regions. (ERMS 232281)
Removed Panel Closures	-11	APCS	Taken to mimic the operational and experimental areas, using the same logic and additional sensitivity tests showing high values are conservative for repository performance.
Panel closures, early times	-14.1*	AP129	Values were initially calculated from laboratory measurements of consolidated salt (Hansen and Knowles 2000) averaged by volume with an explosion wall.
	Uniform dist. -20.84- -12	**CRA14BL, SEN4, APCS**	**Current values were updated with laboratory measurements of permeabilities over the range of predicted porosities to produce the given distribution.**
	-22.5	CRA14_SEN3	CRA14_SEN3 tested extremely low permeabilities taken to mimic undisturbed halite for the duration of the simulation.
Panel closures, transitional times	Triangular dist. -22.8- -17.6	AP129-PC3R	Values were calculated from laboratory measurements on consolidated salt (Hansen and Knowles 2000).
	-18.6[#]	**CRA14_BL-APCS**	**Current values were updated with a porosity permeability relationship derived from laboratory data (Brodsky 1994) as shown in Camphouse (2012).**
Panel closures, late times	-19.1[#]	CRA14BL-APCS	Values were updated with a porosity permeability relationship derived from laboratory data (Brodsky 1994) as shown in Camphouse (2012).

*Values are isotropic, only X-direction values are shown here.

[#] Actual range is calculated according to Camphouse (2012). Value shown is average of minimum and maximum.

A.2.a. Overarching Questions

2. Is DOE aware of other modeling studies that contradict EPA's understanding of creep closure rates and/or end-state parameter values?

RESPONSE

The basis for DOE's understanding of creep closure processes is summarized in the DOE/EPA Technical Exchange presentation, "Overview of Open Room Closure." DOE continues to investigate end state properties of the salt in open areas as described in the DOE/EPA Technical Exchange presentation, "Ongoing Research Related to Open Room Closure," which will support parameter assessments for CRA-2024.

A.2.a. Overarching Questions

3. Are there specific studies or conclusions in EPA's TSD that DOE believes should be reconsidered?

RESPONSE

DOE is reconsidering its conceptual model of open room closure as summarized in the DOE/EPA Technical Exchange presentation, "Overview of Open Room Closure." Associated research plans are described in the DOE/EPA Technical Exchange presentation, "Ongoing Research Related to Open Room Closure," which will support parameter assessments for CRA-2024.

A.2.b. EPA Questions on DOE's Analysis Plans

Sandia National Laboratories

<u>AP-178</u> – Questions pertaining to AP-178 (Reconsiderations of the WIPP Geomechanical Model for Room Closure Model):

> In Section 3.1.2, it is indicated that that the older MD model under-predicts closure rates. What is the basis for this conclusion? Please provide more information regarding the extent of these under-predictions as a function of time.

RESPONSE

The basis is provided by Reedlunn (2016), Fig. 1.11. Reedlunn reports the results of Munson et al. (1986), showing the extent of the under-predictions as a function of time. More recent MD model calibrations (Cal 1A and Cal 1B) also under-predict the closure of Room D (Reedlunn (2016), Fig. 4.1). Fortunately, the predictions were significantly improved upon modifying the MD model to capture the creep at low equivalent stresses (Reedlunn (2018)). The DOE/EPA Technical Exchange presentation, "Ongoing Research Related to Open Room Closure," presentation addresses this topic.

A.2.b. EPA Questions on DOE's Analysis Plans

AP-178 – Questions pertaining to AP-178 (Reconsiderations of the WIPP Geomechanical Model for Room Closure Model):

Does DOE have an idea if there are multiple phases to room closure rates (e.g., stepped thresholds)?

RESPONSE

The volumetric closure rate changes during the transition from transient creep to steady-state creep, when fractures change the shape of the room, when the ceiling and floor contact the contents of the room, and when the gas/brine pressure in the room changes. The DOE/EPA Technical Exchange presentation, "Ongoing Research Related to Open Room Closure," addresses these effects in varying levels of detail.

A.2.b. EPA Questions on DOE's Analysis Plans

AP-178 – Questions pertaining to AP-178 (Reconsiderations of the WIPP Geomechanical Model for Room Closure Model):

> Can DOE assess the reliability of the Morgan 1986 estimates (98 % room closure at 200 years)?

RESPONSE

Morgan's estimate is not credible for several reasons. He did not include discrete fractures, gas/brine pressure in the room, anhydrite strata, or clay seams. His salt constitutive model did not include the creep at low (< 8 MPa) equivalent stresses, and he compensated by reducing salt's elastic stiffness by a factor of 12.5. He also did not have the computational power to accurately resolve the numerics (see Chapter 2 of Reedlunn (2016)).

A.2.b. EPA Questions on DOE's Analysis Plans

<u>AP-178</u> – Questions pertaining to AP-178 (Reconsiderations of the WIPP Geomechanical Model for Room Closure Model):

Can DOE please provide a copy of Herrick et al. 2017 (TP 17-02), which is a test plan referenced in Section 3.2?

Are any other tests being planned? If so, please describe the tests and provide copies of the relevant test plans.

RESPONSE

TP 17-02 and all relevant test plans have been provided to the EPA. Joint Project WEIMOS has been performing healing tests and creep tests at low equivalent stresses on WIPP salt, but test plans do not exist for those experiments.

A.2.b. EPA Questions on DOE's Analysis Plans

<u>AP-179</u> – Questions pertaining to AP-179 (Modifications to the Munson-Dawson Model):

> Can DOE assign general time frames (in 100 to 150 time increments) to the larger scale mechanistic processes (such as of roof fall, floor heave-rib exfoliation, cataclysm, consolidation and compression) versus the processes that act on varying size spall aggregates at the microscopic scale (i.e., fluid assisted diffusion and deformation, grain boundary deformation, etc)?

RESPONSE

Macroscale processes are a result of the microscale processes. DOE will continue to investigate when large chunks of rock will fall into a drift, and when the resulting rubble pile begins to heal.

A.2.b. EPA Questions on DOE's Analysis Plans

<u>AP-179</u> – Questions pertaining to AP-179 (Modifications to the Munson-Dawson Model):

When are confining pressures that can heal microfractures expected to be achieved?

RESPONSE

The salt around an open drift and the rubble pile inside an open drift will have both microscopic and macroscopic fractures. The fractures should begin to heal in 50 to 1000 years after excavation. Further study is needed to reduce this range.

References

Brodsky, N.S. (1994). Hydrostatic and Shear Consolidation Tests With Permeability Measurements on Waste Isolation Pilot Plant Crushed Salt. Sandia National Laboratories. Albuquerque, NM. SAND93-7058.

Butcher, B.M.. (1996). Porosity of the WIPP North End Excavations. ERMS232281

Callahan G.D. and K.L. DeVries. 1991. Analyses of Backfilled Transuranic Wastes Disposal Rooms. Sandia National Laboratories. SAND91-7052.

Camphouse, C.R., M. Gross, C.G. Herrick, D.C. Kicker, and B. Thompson. (2012). Recommendations and Justifications of Parameter Values for the Run-of-Mine Salt Panel Closure System Design Modeled in the PCS-2012 PA. ERMS557396

Hansen, F.D. and M. K. Knowles. (2000). Design and Analysis of a Shaft Seal system for the Waste Isolation Pilot Plant. Reliability Engineering and System Safety. Vol. 69 (2000) 87-98. SAND99-00904J

Munson, D. E., T. Torres, and D. Blankenship, (1986) Early results from the thermal/structural in situ test series at the WIPP, in The 27th US Symposium on Rock Mechanics (USRMS), American Rock Mechanics Association

Reedlunn, B., (2016). Reinvestigation into closure predictions of Room D at the Waste Isolation Pilot Plant. Tech. Rep. SAND2016-9961, Sandia National Laboratories, Albuquerque, NM, USA.

Reedlunn, B., 2018. Joint Project III on the Comparison of Constitutive Models for the Mechanical Behavior of Rock Salt: Reinvestigation into
Isothermal Room Closure Predictions at the Waste Isolation Pilot Plant. (Submitted to) Proc. 9th Conference on the Mechanical Behavior of Salt.

Vaughn, P. (1996). Northend regions (‘Backfill and Experimental’) Porosity. ERMS236320