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Sandia National Laboratories
Waste Isolation Pilot Plant

Structural Evaluation of WIPP Disposal Room Raised to Clay Seam G

AP-093

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	Print	Signature	Date
Author:	Byoung Yoon Park (6821)	*Original signed by Byoung Yoon Park*	*12/9/2002*
Technical Review:	Tom W. Pfeifle (6822)	*Original signed by Tom W. Pfeifle*	*12/9/2002*
Management Review:	Francis D. Hansen (6822)	*Original signed by F.D. Hansen*	*12/9/02*
QA Review:	Mario Chavez (6820)	*Original signed by Mario Chavez*	*12/9/02*

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1 INTRODUCTION AND OBJECTIVES

This analysis plan is necessary to determine the structural response of waste-filled disposal rooms raised 2.43 meters above the present level. The analysis period is 10,000 years after waste emplacement. The calculations of the mechanical creep closure response of a disposal room with waste but without crushed salt backfill will be performed to allow three-dimensional porosity surfaces (Figure 1) to be constructed for WIPP performance assessment activities. On the basis of the calculations, an assessment will be made whether raising the repository to Clay Seam G has any significant impact on the conceptual models used in performance assessment.

The WIPP management and operating contractor, Westinghouse TRU Solutions (WTS), has asked permission of the EPA to raise the disposal room 2.43 m above the present level. This change means the roof of a disposal room would coincide with the Clay Seam G horizon and the floor would be separated from the underlying Marker Bed 139 by 3.81 m instead of 1.38 m (the existing separation in disposal panels 1 and 2). The structural implications of raising the repository horizon will be assessed using the calculations described in this Analysis Plan.

The change in repository horizon was recommended to ease ground control conditions. Fractures surrounding the existing horizon tend to coalesce in an arch, which mimics the shear stress trajectories. These patterns can be seen in the underground today where the roof has been taken down along the length of the East 140 drift. The roof rock of the original horizon tends to de-couple at Clay G, as exhibited by the shear fracture patterns. Underground operations personnel are currently obligated to provide roof support and maintenance that they believe would be unnecessary if the roof of the disposal rooms is raised to Clay G. Because this change incorporates geometry in the WIPP underground that is different from the compliance baseline as modeled for the compliance application, it is necessary to evaluate the impact of this proposed mining change.

This analysis will be based on the “Final Disposal Room Structural Response Calculations, SAND97-0795” (Stone, C.M., 1997), which is the referenced baseline report for the CCA. Calculation procedures and data of SAND97-0795 will be used in this analysis and the results of this analysis will be compared with the results of SAND97-0795. Therefore, the initial calculations will replicate room pressure and porosity histories for various gas generation rates for a period of 10,000 years following excavation and waste emplacement.

2 APPROACH

2.1 Change the elevation of disposal rooms

Figure 2 shows the simplified stratigraphic model used for the disposal room analyses of SAND97-0795 (Butcher, 1997). This stratigraphic model will be changed as shown in

Figure 2 to raise the disposal room by 2.43 m. The mesh for the FEM analysis will be changed as shown in Figure 3. The mesh, excluding the elements immediately adjacent to the room, is the same as the one made by Stone, C.M. (1997). The mesh will be changed as little as possible to minimize the margin of error resulting from the change. The new two-dimensional (2D) mesh will be made by modifying the FASTQ input file of Stone.

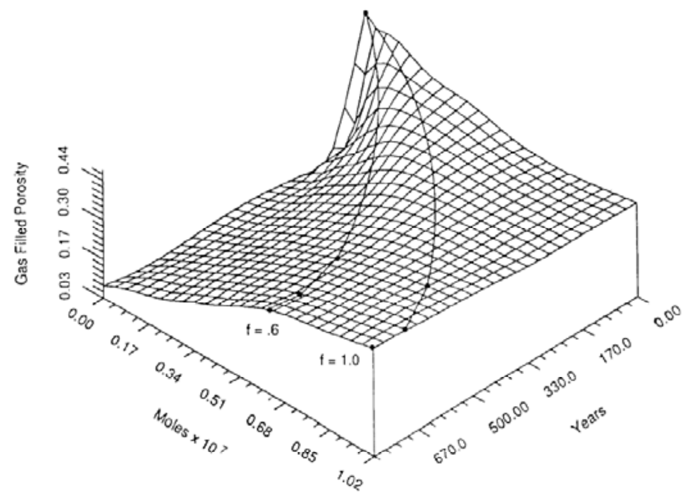

Figure 1: A typical porosity surface

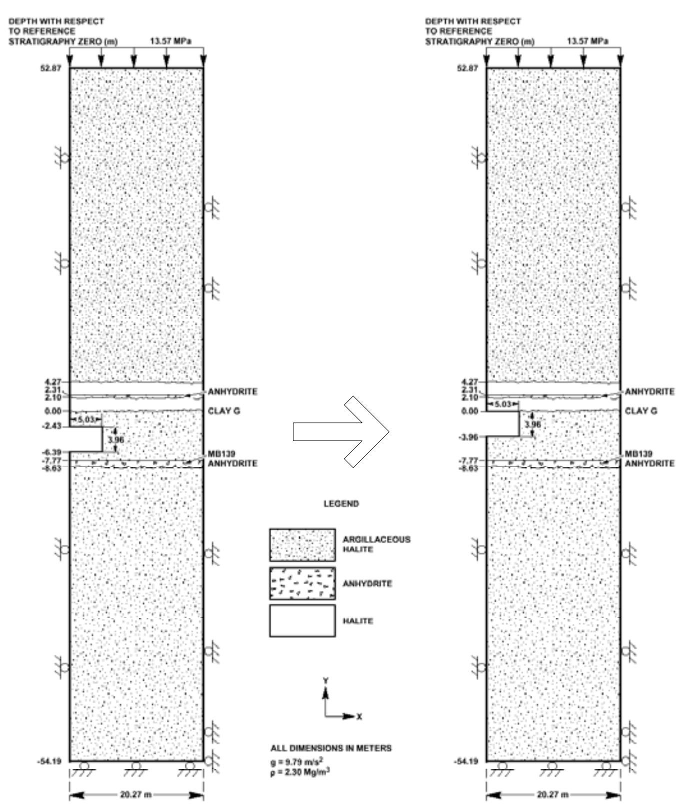

Figure 2: Simplified stratigraphic model used for the earlier disposal room analyses (left) and the new one (right).

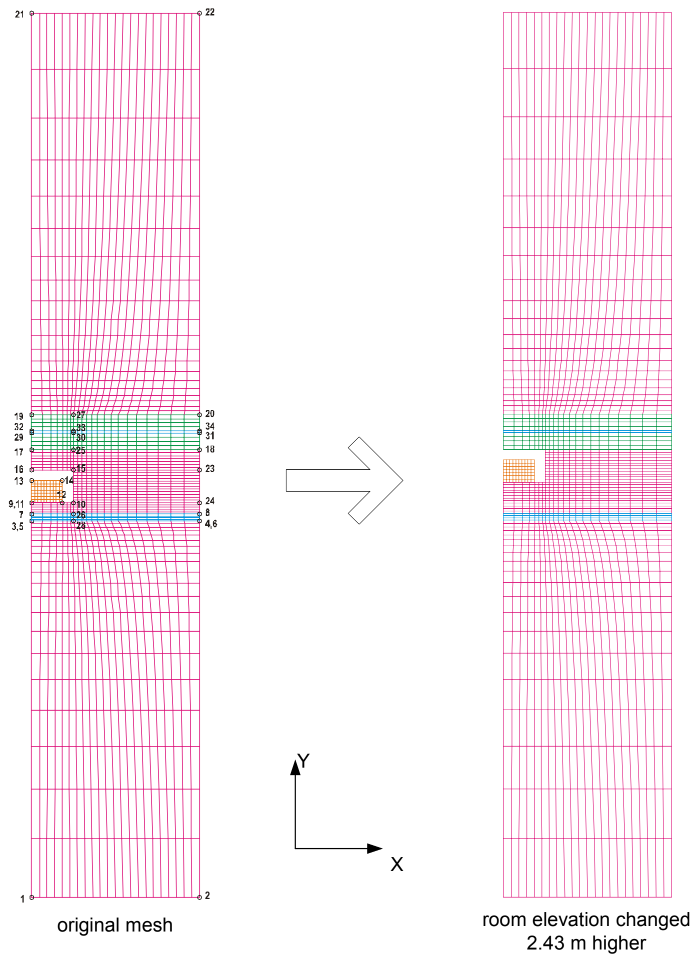

Figure 3: Mesh for FEM analyses

2.2 Solver

The quasistatic, large-deformation finite element code SANTOS (Stone, C.M., 1997), version 2.0.0 installed on the Sandia Cray J916 computer, was used for the earlier analysis. SANTOS is capable of representing 2D planar or axisymmetric solids. The solution strategy, used to obtain the equilibrium states, is based on a self-adaptive, dynamic-relaxation solution scheme incorporating proportional damping. The explicit nature of the code means that no stiffness matrix is formed or factorized which results in a reduction in the amount of computer storage necessary for execution. The element used in SANTOS is a uniform-strain, 4-node, quadrilateral element with an hourglass control scheme to minimize the effects of spurious deformation modes. Finite strain constitutive models for many common engineering materials were available within the code. A robust master-slave contact algorithm for modeling arbitrary sliding contact was implemented.

Recently, an executable SANTOS version 2.1.0 was installed on a Workstation with the Unix operating system. The source code of SANTOS was copied to the Workstation and compiled again. This SANTOS Workstation version will be used in this analysis.

The 2D "M-D Creep Model" (Munson, D.E. and Dawson, P.R., 1982) will be used for argillaceous halite or pure halite. The 2D "Soil n Foams Model" of SANTOS for anhydrite or waste packages also will be used.

2.3 Material data

The SANTOS data for each material will be identical to that used in Stone's analysis (Stone, C.M., 1997). The material constants corresponding to the clean and argillaceous salt, which will be used in the analyses, are given in Table 1 and Table 2.

Table 1: Clean and argillaceous salt elastic properties (Munson et al., 1989)

G MPa	E MPa	ν
12,400	31,000	0.25

Table 2: Salt creep properties (Munson et al., 1989)

Parameters (Units)	Clean Salt	Argillaceous Salt
A_1 (/sec)	8.386E22	1.407E23
Q_1 (cal/mole)	25,000	25,000
n_1	5.5	5.5
B_1 (/sec)	6.086E6	8.998E6
A_2 (/sec)	9.672E12	1.314E13
Q_2 (cal/mole)	10,000	10,000
n_2	5.0	5.0
B_2 (/sec)	3.034E-2	4.289E-2
σ_0 (MPa)	20.57	20.57
q	5,335	5,335
m	3.0	3.0
K_0	6.275E5	2.470E6
c (/T)	9.198E-3	9.198E-3
α_w	-17.37	-14.96
β_w	-7.738	-7.738
δ	0.58	0.58

Table 3 lists the pressure-volumetric strain data used for the waste drum model and the data are plotted in Figure 4. Note that the final point listed in the table is a linear extrapolation beyond the curve given in Butcher (1997). The final pressure (or mean stress) of 12 MPa corresponds to axial and radial stresses on a waste drum of 36 MPa and 0 MPa, respectively. The elastic material parameters and constants defining the yield surface are given in Table 4. The elastic properties and Drucker-Prager constants, C and a, for the anhydrite are given in Table 5. Clay Seams will be treated in a manner consistent with Stone (1997)

Table 3: Pressure-volumetric strain data used in the volumetric-plasticity model for the waste drums (Butcher, 1997)

Pressure (MPa)	ln (ρ/ρ_0)
1.53	0.510
2.03	0.631
2.53	0.719
3.03	0.786
3.53	0.838
4.03	0.881
4.93	0.942
12.0	1.14

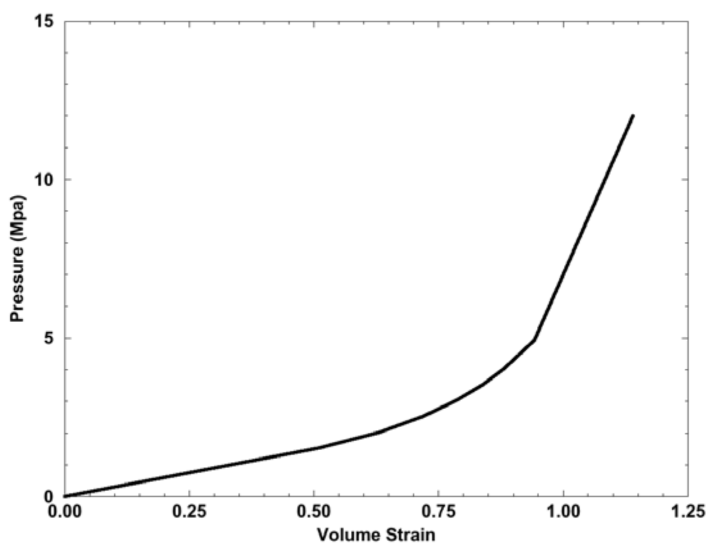

Figure 4: Curve of the pressure-bulk strain input to the volumetric plasticity model used to model the waste drums

Table 4: Material constants used with the volumetric plasticity model for the waste (Butcher, 1997)

Parameter	Value
G	333.0 MPa
K	222.0 MPa
a_0	1.0 MPa
a_1	3.0
a_2	0.

Table 5: Elastic and Drucker-Prager constants for anhydrite (Butcher, 1997)

Material	Young's Modulus (GPa)	Poisson's Ratio	C (MPa)	a
Anhydrite	75.1	0.35	1.35	0.45

2.4 Gas generation potential

The gas generation potential and gas production rate corresponding to the reference case are composed of gas from two sources: anoxic corrosion and microbial activity. Butcher(1997) reports that the estimated gas production potential from anoxic corrosion will be 1,050 *moles/drum* with a production rate of 1 *mole/drum/year*. The gas production potential from microbial activity is estimated to be 550 *moles/drum* with a production rate of 1 *mole/drum/year*. This means that microbial activity ceases at 550 years while anoxic corrosion will continue until 1,050 years after emplacement. The total amount of gas generated in a disposal room for the reference case was specified to be based on the 6,804 unprocessed waste drums per room. The total gas potential for the reference case is shown in Figure 5.

The gas pressure in the disposal room was computed from the ideal gas law based on the current free volume in the room. Specifically, the gas pressure, p_g, was computed with the following relationship:

$$p_g = f \cdot \frac{NRT}{V}$$

where N, R and T are the mass of gas in g-moles for the baseline case, the universal gas constant, and the absolute temperature in degrees Kelvin, respectively. For the current analyses, the absolute temperature is taken to be 300 ºK. The variable is the current free volume of the room. During each iteration in the analysis, the current room volume is calculated based on the displaced positions of the nodes on the boundary of the room. The free room volume, V, is computed by subtracting the solid volume of the waste, 551.2 m^3, from the current room volume. The gas generation variable, f, is a multiplier used in the analyses to scale the pressure by varying the amount of gas generation. A value of *f*=1 corresponds to an analysis incorporating full gas generation, while a value of *f*=0 corresponds to an analysis incorporating no internal pressure increase due to gas generation. This portion of the analysis is identical to that implemented by Stone (1997).

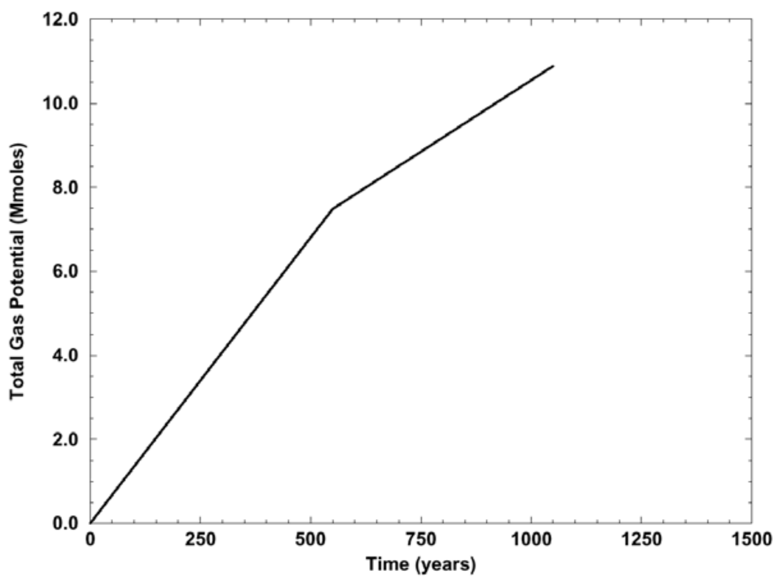

Figure 5: History of the reference gas generation potential used for the disposal room analyses, *f* = 1.0.

2.5 Subroutine

The previous analyses using SANTOS, version 2.0.0 installed on the Sandia Cray J916, were carried out to a simulation time of 10,000 years by Stone (1997). Thirteen cases of gas generation were investigated, these were for *f* = 0.0, 0.025, 0.05, 0.1, 0.2, 0.4, 0.5, 0.6, 0.8, 1.0, 1.2, 1.6, and 2.0. The gas generation parameter, *f*, was set in the user-supplied subroutine FPRES. The FPRES subroutine will be used unchanged in this analysis.

Stone (1997) used the user-supplied subroutine INITST to provide an initial stress state to SANTOS. In this analysis, the INITST subroutine will be used unchanged from Stone (1997).

3 SOFTWARE LIST

All applicable software and version numbers are listed in Table 6.

Table 6: Applicable software and version numbers

Code Name	*Version*
ALGEBRA2	1.15
APREPRO	1.60
BLOT	2.14S
SANTOS	2.1.0
FASTQ	2.1.0
GEN3D	1.16

4 TASKS

The following procedures will be performed to estimate whether raising the repository to Clay Seam G has any significant impact on the conceptual models used in performance assessment:

1. The effects of changing the FEM code on the calculated results will be qualified by comparing the results for the current horizon by SANTOS W/S version with the one by Stone (1997). That means, first the baseline results provided by Stone (1997) will be replicated.

2. The effects of raising the room 2.43 m will be calculated. The results for the disposal room raised 2.43 m will be compared with the baseline results replicated for the current horizon by SANTOS W/S version

3. Displacement data of the disposal room and wastes from SANTOS W/S version analyses will be converted into the porosity data by ALGEBRA. 3D porosity surface will be made of these porosity data with the gas generation potential and time.

4. The structural implication of raising the room 2.43 m will be evaluated by:

    - Comparing MB139 to a failure criterion

    - Examining stress conditions in the salt with respect to a damage function

Byoung Yoon Park will perform the analysis and be assisted in documentation by Tom W. Pfeifle and Francis D. Hansen. Mario Joseph Chavez will perform the QA procedures assisted by Jose A. Archuleta. Quality insurance documentation, calculation runs, analysis and documentation are planned to be completed as expeditious as possible.

5 SPECIAL CONSIDERATIONS

No special considerations have been identified for this analysis.

6 APPLICABLE PROCEDURES

Analyses will be conducted in accordance with the quality assurance (QA) procedures listed below:

Training: Training will be performed in accordance with the requirements in NP 2–1, Qualification and Training.

Parameter Development and Database Management: Selection and documentation of parameter values will follow NP 9–2. The database is to be managed in accordance with relevant technical procedure.

Computer Codes: New or revised computer codes that will be used in the analyses will be qualified in accordance with NP 19–1. Codes will be run on the Compaq Tru64 UNIX V5.1A (Rev. 1885).

Analysis and Documentation: Documentation will meet the applicable requirements in NP 9–1.

Reviews: Reviews will be conducted and documented in accordance with NP 6–1 and NP 9–1, as appropriate.

7 REFERENCES

Butcher, B.M. 1997, *A Summary of the Sources of Input Parameter Values for the WIPP Final Porosity Surface Calculations*, SAND97-0796, Albuquerque, NM: Sandia National Laboratories.

Munson, D.E., and Dawson, P.R., 1982. *A Transient Creep Model for Salt during Stress Loading and Unloading,* SAND82-0962. Albuquerque, NM: Sandia National Laboratories.

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