ISO-2 Project WIPP Independent Oversight – DE-AC30-06EW03005

AN EVALUATION OF THE APPROVED AND PROPOSED PANEL CLOSURE SYSTEMS AT THE WASTE ISOLATION PILOT PLANT

October 2006

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ISO-2 Project
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ACRONYMS

CBFO	Carlsbad Field Office
CCA	Compliance Certification Application
CH	contact-handled
CMU	concrete masonry unit
CO_2	carbon dioxide
CPR	cellulosics, plastics, and rubbers
CRA	Compliance Recertification Application
DOE	U.S. Department of Energy
DRZ	disturbed rock zone
EEG	Environmental Evaluation Group
EPA	U.S. Environmental Protection Agency
HW	hazardous waste
LWA	Land Withdrawal Act
NAS	National Academy of Science
NMED	New Mexico Environment Department
O_2	oxygen
QA/QC	quality assurance/quality control
RCRA	Resource Conservation and Recovery Act
RH	remote-handled
SMC	Salado mass concrete
TRU	transuranic
VOC	volatile organic compounds
WIPP	Waste Isolation Pilot Plant
WPC	waste panel closure

EVALUATION OF THE PURPOSE AND NEED FOR PANEL CLOSURE AT THE WIPP

October 2006

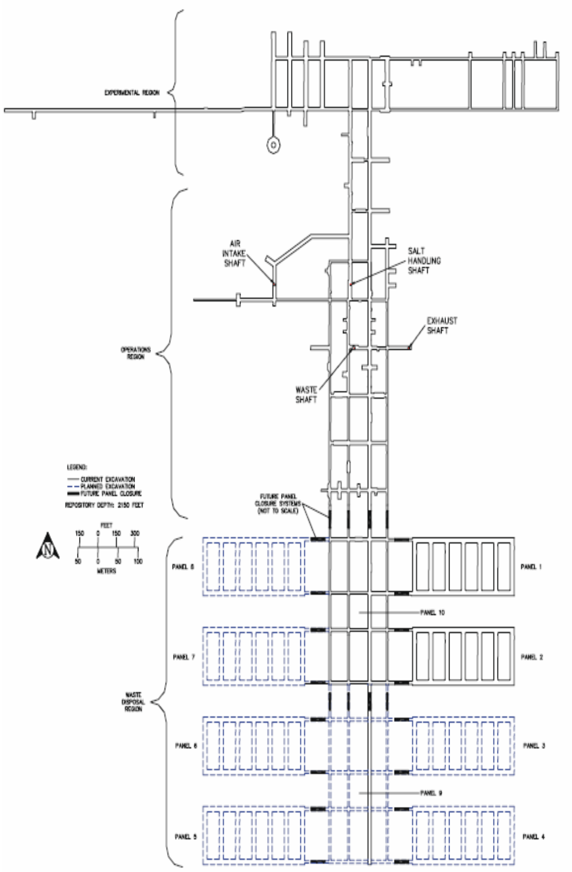
I. SCOPE AND PURPOSE

The purpose of this report is to review documentation and other information concerning the requirements and associated designs relating to the closure of underground waste disposal panels in the Waste Isolation Pilot Plant (WIPP). The report provides a summary of requirements for the panel closure systems and an overview of the evolution of panel closure design concepts and their technical bases. The reviewers have evaluated both current and proposed panel closure system designs and have provided conclusions and recommendations. Materials reviewed include the text and selected appendices of selected applicable laws and regulations, the *Compliance Certification Application (CCA),*[1] the *2004 WIPP Compliance Recertification Application (CRA),*[2] the *Hazardous Waste (HW) Treatment Facility Permit for the Waste Isolation Pilot Plant,*[3] and permit modification requests, design documents, technical papers, peer review reports, and presentations made to PECOS by personnel from the U.S. Department of Energy (DOE), Carlsbad Field Office (CBFO), and contractors and subcontractors supporting the WIPP.

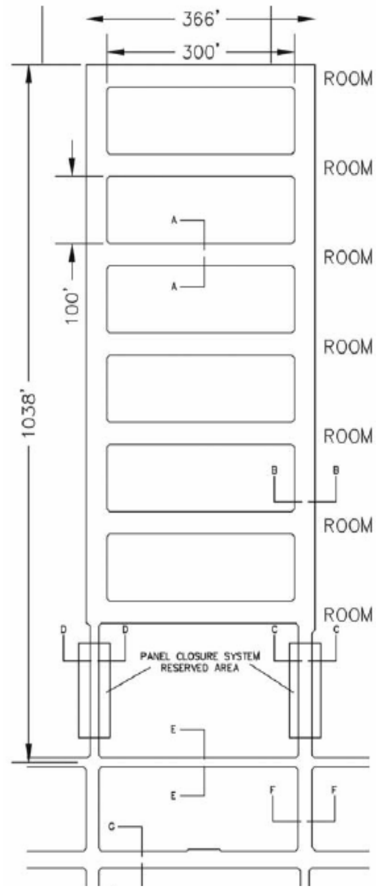
II. BACKGROUND

The mission of the WIPP project is to carry out the final disposition of the legacy transuranic (TRU) and TRU-mixed waste remaining from the United States' nuclear weapons program. That waste consists of both contact-handled (CH) and remote-handled (RH) TRU wastes that contain various radionuclides, certain volatile organic compounds (VOC), and cellulosics, plastics, and rubbers (CPR). This waste is, or will be, transported to the WIPP site near Carlsbad, NM for disposal 2,150 feet underground in a 1,950-foot-thick, geologically stable, 250-million-year-old salt bed called the Salado Formation[1].

The WIPP repository consists of an arrangement of panels and rooms that will be used for the final disposal of the TRU and TRU-mixed waste. *Figure 1.a* is a plan view of the WIPP repository, which shows the layout of the major shafts and tunnels as well as the 10 waste disposal panels. The shafts and tunnels provide workforce access and offer routes for mined salt removal, waste transportation, and intake and exhaust air. *Figure 1.b* is an enlarged view of the typical waste disposal panel layout. Waste disposal panels 1 through 8 consist of two drifts that are excavated perpendicular to the main tunnels extending



1a. Plan View of WIPP Underground Facility and Panel Closure Systems



1b. Underground Waste Disposal Panel

Figure 1. Plan views of WIPP (from Compliance Recertification Application 2004, Reference 2).

approximately 1,038 feet into the Salado Formation. One is designated as the intake drift, the other as the exhaust drift. The disposal rooms are formed by excavations perpendicular to and connecting the two drifts. The rooms are separated from one another by a wall of salt that is 100 feet thick. The exhaust drift is 14 feet wide by 12 feet high, and the intake drift is 20 feet wide by 13 feet tall. Panel 9 encompasses the four drifts that extend from the southernmost drift of Panels 4 and 5 to the northernmost drift of Panels 3 and 6. Panel 10 encompasses the four drifts running from the point of closure of Panel 9 to the northernmost drift of Panels 1 and 8. After each room and panel are filled, the openings to the main repository drifts, namely the exhaust and intake drifts, are to be closed.[3]

The design and operating requirements of the WIPP are intended to ensure worker and public safety during the operating life of the WIPP and to prevent accidental release of radioactive or hazardous constituents and consequent human exposure for at least 10,000 years after the plant's closure. These requirements are derived from the following sources:

1. **The Waste Isolation Pilot Plant Land Withdrawal Act** (LWA)**,** as amended.[4] Section 8 of the LWA requires DOE to:

    a. Meet the requirements established by DOE for radioactive waste disposal facilities in general (40CFR191),
    b. Comply with the criteria established by the Environmental Protection Agency (EPA) for its certification of compliance with 40CFR191, codified in 40CFR194, and
    c. Use both engineered and natural barriers plus any other measures (including waste form modifications) to the extent necessary to comply with final disposal regulations.

    The LWA defines engineered barriers as "backfill, room seals, panel seals, and any other manmade barrier components of the disposal system."

2. **40 CFR Part 191** – *Environmental Radiation Protection Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level, and Transuranic Radioactive Wastes.*[5] Subparts 191.12 and 191.14(d) of this regulation establish the environmental standards for radioactive waste disposal facilities for both the operational period and the post-closure period. This regulation, whose requirements are applicable only to radioactive materials and wastes, specifies that any combination of engineered or natural barriers shall be used to isolate the wastes from the accessible environment. Barrier is defined as "any material or structure that prevents or substantially delays the movement of water or radionuclides toward the accessible environment."

3. **40 CFR Part 194 –** *Criteria for the Certification and Re-Certification of the Waste Isolation Pilot Plant's Compliance with the 40 CFR Part 191 Disposal Regulations*.[6] EPA used the procedures stated in this regulation as a basis for its approval of the CCA and the CRA, including evaluation of the effectiveness of any engineered barriers for preventing or delaying the movement of water or radionuclides toward the accessible environment both during operations and post-closure. It also established specific criteria or conditions that must be included and evaluated in the CCA and any subsequent recertification.

4. **Resource Conservation and Recovery Act (RCRA).**[7] Under RCRA, the WIPP is defined as a Miscellaneous Unit. Per 40 CFR 264.601(c)(2), control systems must be included in the construction, operation, and closure of WIPP to reduce or prevent emissions of hazardous constituents to the air.[12] For the WIPP, the primary RCRA concern was a potential release of

unacceptable levels of VOCs from TRU mixed wastes placed in the waste disposal panels during the 35-year design life of the repository. A secondary concern was the possibility that the wastes would generate enough hydrogen or methane to result in an explosive mixture in the repository. Approval of the control systems required by the above regulation is the responsibility of the New Mexico Environment Department (NMED), under delegation from the EPA. That approval is contained in the HW permit.

5. **30 CFR 57–** Subpart T, *Safety and Health Standards, Underground Metal and Nonmetal Mines*.[8] These regulations include the hazards of methane gas and volatile dust. Category IV "applies to mines in which non-combustible ore is extracted and which liberate a concentration of methane that is neither explosive nor capable of forming explosive mixtures with air based on the history of the mine or the geological area in which the mine is located." This regulation addresses ventilation and safety requirements for Category IV mines but does not require any form of barrier for areas of a Category IV mine that are no longer active workings.

The DOE evaluated numerous alternate panel closure systems against the above regulatory requirements as a part of its preparation of the CCA and the RCRA Part B application. These evaluations indicate that requirements for panel closure systems were primarily RCRA-driven and established the following panel closure system design requirements:

1. The panel closure system shall limit VOC migration from a closed panel consistent with the limits found in Table IV.F.2.c of the HW Permit.
2. The panel closure system shall consider potential flow of VOCs through the disturbed rock zone (DRZ) in addition to flow through closure components.
3. The panel closure system shall perform its intended functions under loads generated by creep closure of the tunnels.
4. The panel closure system shall perform its intended function under the conditions of a postulated methane explosion (pressure rise of 240 psi).
5. The nominal operational life of the closure system is thirty-five (35) years.
6. The panel closure system for each individual panel shall not require routine maintenance during its operational life.
7. The panel closure system shall address the most severe ground conditions expected in the waste disposal area.
8. The design class of the panel closure system shall be IIIb (meaning it is to be built to generally accepted national design and construction standards).
9. The design and construction shall follow conventional mining practices.

10. Structural analysis shall use data acquired from the WIPP underground.
11. Materials shall be compatible with their emplacement environment and function.
12. Treatment of surfaces in the closure areas shall be considered in the design.
13. Thermal cracking of concrete shall be addressed.
14. During construction, a QA/QC program shall be established to verify material properties and construction practices.
15. Construction of the panel closure system shall consider shaft and underground access and services for materials handling.[3]

The hierarchy of these DOE design requirements for the panel closure system, which comply with 20.4.1.500 NMAC (incorporating 40 CFR §264.601(a)), reinforce the intent of DOE that the panel closure system is to control VOCs and mitigate the effects of pressure buildup in a closed panel during the operational life of the repository.

Using these design requirements and the available information relating to the key design parameters, such as VOC concentrations in the waste, possible reactions in disposed waste, salt creep, brine movement, etc., the DOE developed and submitted four alternate panel closure designs that met the above design requirements as part of the CCA. These designs were intended to be applied to different panels based upon the characteristics of the waste disposed in a particular panel, the condition of the surfaces of the drifts to be closed, and the time of installation relative to the remaining active disposal life of the repository. The CCA indicated that none of the four options were intended or designed to meet the long-term, post-closure requirements established by 40CFR191.

All four options share three main features: 1) a dense concrete block wall constructed close to the end of waste deposits in the panel; 2) an open space of approximately 100 feet in the drift; and 3) a concrete barrier constructed at the junction of the panel drifts with the first main repository drift *(Figure 2)*. The purpose of the dense concrete block wall is to isolate disposed wastes from ongoing activities in the repository and to protect workers from any effects of gas generation or brine accumulation in the closed panel. The monolithic concrete barrier component is intended to be the primary barrier to the flow of air, volatile organic compounds, and brine that enter through the panel access drift once the waste disposal panel has been closed. The open space appears to have been designed primarily to allow sufficient space for construction of the monolithic concrete barrier. The four options differ from one another in the manner in which they are keyed into the sides, floor, and ceiling of the drifts as well as in the thickness of the concrete block walls. (DOE also submitted a fifth option to the NMED as a part of its HW permit application, which proposed installing only the dense concrete block wall portion.)

EPA reviewed the four panel closure system options proposed by DOE and determined that a panel closure system would indeed be beneficial in preventing the existing disturbed rock zone (DRZ), a zone of higher permeability salt resulting from both construction disturbances and salt creep after panel construction, in the panel access drifts from increasing in permeability following panel closure. However, EPA was concerned that the concrete formulation proposed for the monolithic barrier would not adequately withstand degradation over time. Consequently, EPA determined that implementation of the most robust of the four proposed panel closure options, "*would be adequate*" to achieve the long-term performance requirements of 40CFR191 if constructed with Salado mass concrete (SMC) instead of fresh water concrete.[2] (SMC is concrete made with brine formulated from Salado salt.) EPA included this determination as a component of its approval of the CCA in 1999. The NMED also included that same option as the required panel closure system in the HW permit issued later in 1999.

As shown in *Figure 2*, the approved panel closure system consists of a 12-foot-thick explosion/isolation wall constructed of dense concrete masonry units (CMU) followed by a 28-foot-thick SMC monolithic concrete barrier, which is anchored in a circular-type groove cut into the host rock. Cutting of the groove results in removal of most of the DRZ. Removal of the DRZ *prior* to construction of the monolithic concrete barrier portion of the panel closure system insures consistency in the initial characteristics of the interface between the Salado host rock and the concrete barrier. The bottom of the monolithic concrete barrier is keyed into marker bed 139, and the top keys into the clay G zone, essentially blocking diffusion of VOCs through the cracks in the DRZ. The two barriers are separated by an isolation zone.
The sequence for panel closure begins with the closure of individual rooms after they have been filled with wastes. Module IV of the HW permit requires ventilation barricades to be installed on each filled disposal room and refers to Attachment M2 of the HW permits which states, "*Once a disposal room is filled and is no longer needed for emplacement activities, it will be barricaded against entry and isolated*

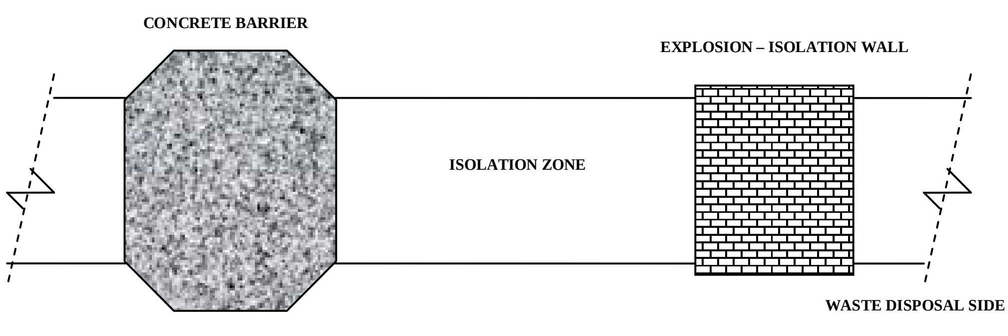


Figure 2. Approved Panel Closure System - Explosion isolation wall and Salado Mass Concrete barrier with DRZ removed.

from the mine ventilation system by removing the air regulator bulkhead and constructing chain link/brattice cloth barricades at each end."[3] When the last room (Room 1) of the panel is filled, these ventilation barricades would be installed across the intake and exhaust drifts of the panel between the main drift and Room 1. The permanent panel closure system approved by EPA and NMED would then be installed according to the schedule established in the HW permit. Locations of the panel closure system for each of the 10 panels are depicted in solid black in *Figure 1.a*.

The schedule for panel closure as originally established in the HW permit, Attachment I, required room barricades to be installed immediately upon completion of a panel; the installation of the panel closure system was to start within 30 days of panel closure and was to be completed within 17 months. (Panel 1 had an expedited closure schedule since waste disposal in it was curtailed due to structural instability issues with the rooms).

Subsequent to the EPA stipulation of the required panel closure system and the consequent inclusion of that requirement in the HW permit, DOE expressed concern that the use of SMC during installation of the approved panel closure system could have possible impacts on waste management activities in the WIPP underground. This concern was reinforced by the erratic results of several test pours of the SMC formulation that was specified in the WIPP HW permit.[9] As a result, in 2002, DOE submitted a permit modification request (PMR) to the NMED and to EPA requesting approval of an amended waste panel closure (WPC) system.[10] The PMR states that the alternative system proposed by DOE (*Figure 3*) is somewhat simpler in design, less expensive, much faster to construct, equally protective, has less impact to facility operations, and has a higher certainty of success. It consists of a 30-foot-thick explosion-isolation barrier backed up by a 100-foot run of mine salt backfill.

Prior to constructing the barrier, any loose materials from the ribs, floor, and ceiling of the drift to be closed would be removed in order to create a clean and even surface, and dense CMUs would then be laid with offsetting mortar joints. (The composite permeability was shown to be on the order of 10^{-15} m^2).[11]

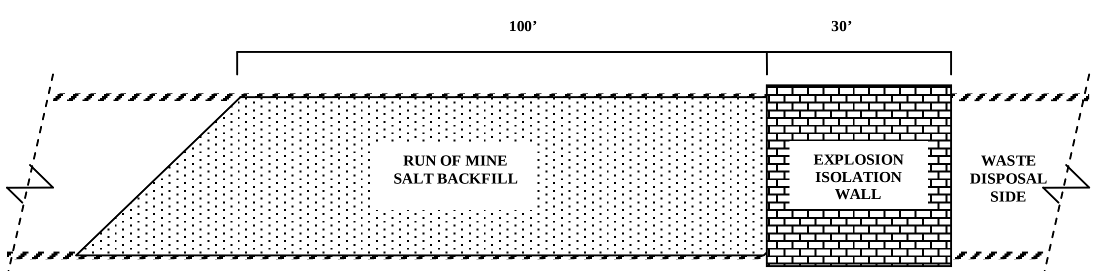


Figure 3. Explosion isolation wall in combination with the run of mine salt backfill.

Sandia National Laboratory evaluated this revised panel closure system for compliance with 40CFR191 and determined that the proposed change was indeed compliant with 40CFR191.[12]

Following a series of meetings and discussions between EPA and DOE, it was determined that EPA would defer its consideration of DOE's proposed WPC system modification until after approval of the CRA for the operating period of 2005 to 2009. NMED in turn, deferred its consideration of the proposed system until a decision regarding the 2002 PMR was reached. EPA and NMED both agreed to defer construction of the SMC monolithic concrete barrier pending completion of the review of the WPC system.[13]

In December 2002 NMED approved a Class 1* Modification Request for the HW permit, which stipulated that the explosion/isolation wall for Panel 1 was to be completed within 180 days of final placement of waste in that panel, and that the panel closure system was to be completed no later than five years following completion of that wall.[14] In July 2005, NMED approved a revised closure schedule for Panel 2.[15] To date, Panels 1 and 2 have each been closed with a 12-foot-thick CMU explosion/isolation wall. However, following construction of the Panel 1 explosion/isolation wall, the dense CMU block size was changed to half the length of its original size. NMED was notified as to this design change in August 2004.

III. SUMMARY OF FINDINGS

This section reviews the design criteria and data used for the design evaluation submitted with the CCA and Part B Permit Application, the basis for the selection of the approved panel closure system, and the data used to design the alternative panel closure system.

III.A. Selection of Approved Panel Closure System

40 CFR 194.44(a) requires that the WIPP "*disposal systems shall incorporate engineered barriers designed to prevent or substantially delay the movement of water or radionuclides toward the accessible environment*."[5] To meet this requirement, Chapter 3 of the CCA submitted by DOE identified four types of engineered barriers that were incorporated into the design of the disposal system:

(1) shaft seals,
(2) panel closures,
(3) backfill around the waste, and
(4) borehole plugs.

The CCA further specified, "*Panel closures will limit the communication of brine and gases among waste disposal panels*."[1]

In the more specific discussion of the panel closure system in Chapter 3, Section 3.3.2 of the CCA, the DOE noted: "*Panel closures have been included for the purpose of Resource Conservation and Recovery Act (RCRA) disposal unit closure and to prevent potentially unacceptable levels of volatile organic compound release during waste management operations. The panel closure system was not designed or intended to support long-term repository performance. The panel closures do, however, provide a solid within the drifts which prevent the preexisting DRZ from increasing in permeability after closure system installation.*"[1] Based on the statement that the panel closure systems were intended to meet the requirements of 40CFR194, the EPA had no choice but to include them in its certification of the WIPP. However, it appears that while the EPA opted for the most robust of the four proposed panel closure systems to prevent permeability increases, it did so without the benefit of scientific evaluation regarding the effectiveness of any of the four proposed options. Also, though the EPA made its decision to require the use of SMC in the selected panel closure system, there is no indication the EPA was presented with or evaluated any scientific data related to concrete degradation beyond that presented in Appendix PCS to the CCA .

III.B. Design Criteria

As indicated by the design requirements summarized above, specific design criteria were required for 1) the control of VOCs associated with wastes, 2) naturally occurring methane gas, 3) gases expected to be generated by the wastes after placement in a panel, 4) salt creep, and 5) possible brine buildup.

VOCs. The HW permit regulates the control of hazardous constituents for the WIPP. The VOCs of concern include carbon tetrachloride, chlorobenzene, chloroform, 1,1-dichloroethane, 1,2-dichloroethane, methylene chloride, 1,1,2,2-tetrachloroethane, toluene, and 1,1,1-trichloroethane. Attachment I of the HW permit[1] sets limits for these VOCs (as shown in *Table 1)* for two locations in the repository: 1) any single room within a panel, and 2) in the E-300 drift (the main drift) at Station A, which is the sampling point located downstream of all panels.

The design criteria related to these limits is the allowable concentration of VOCs at the outer (drift) face of the panel closure system and the single room concentrations limits displayed in *Table 1*. The allowable concentration at the outer face is based upon the allowable concentration of each VOC at the main repository drift (drift E-300), multiplied by the minimum allowed airflow rate required by the HW permit. These two concentrations are used to calculate the permeability of the panel closure system necessary to reduce the single room limits to the concentrations allowed at the outer face of the system. Values for carbon tetrachloride were used to calculate allowable maximum permeability of the barriers because carbon tetrachloride has the most restrictive health-based requirements. The result of these calculations, which were presented in the *Detailed Design Report for an Operational Phase Panel Closure System*,[16] indicated that the permeability of the panel closure system must be not greater than 10^{-15} m^2 assuming VOC concentrations in the closed panel would be at or above the room limits.

Table 1 - VOC Concentrations of Concern

Compound	Room Limits *Mole/room/yr*	Drift *ppmv*	E-300 *ug/m3*	Concentration *ppbv*
Carbon Tetrachloride	4250	9625	1050	165
Chlorobenzene	13000	5500	1015	220
Chloroform	9930	4860	890	180
1,1-Dichloroethene	5490	2800	410	100
1,2-Dichloroethane	2400	1160	175	45
Methylene Chloride	100000	53650	6700	1930
1,1,2,2-Tetrachloroethane	2960	1300	350	50
Toluene	11000	4780	715	190
1,1,1-Trichloroethane	33700	14880	3200	590

(From Attachment I to the HW permit for the WIPP – Reference 3)

Naturally Occurring Methane Gas. As stated in Appendix PCS to the CCA and Attachment I1 to the HW Permit, DOE considered the WIPP a Category IV mine because of the presence of small natural gas occurrences within the repository.[1, 3] However, no information regarding such occurrences (e.g. frequency and concentration)—or concerning any measurements of naturally occurring methane in the Salado Formation or the repository—is provided in either the CCA, CRA, or HW permit. Therefore, no design criteria have been identified for this concern.

Gas Generation by Wastes. The detailed design report[16] presented the design criterion for gas generation as a rate of 8,200 moles per panel per year (0.1 moles per drum per year) due to microbial degradation. However, there was no information regarding composition of the gas that would be generated. It appears the potential for gas generation by other mechanisms (radiolysis and anoxic corrosion) was considered minimal, since no design criteria were established.

Salt Creep. DOE used an estimated creep closure rate of about two percent per year for the panels,[16] which was computed to be an expected volumetric closure rate of 28,000 cubic feet (800 cubic meters) per year per panel due to salt creep.

Brine Inflow. There was no specific discussion presented in any of the documentation reviewed regarding expected timing and volume of brine inflow after a panel is filled and closed or during the operating life of the repository. The only information relevant to the possibility of brine impact on the panel closure system is provided in Attachment I1 of the HW permit,[3] which states, "*The trace amounts of brine from the salt at the repository horizon should not degrade the main concrete barrier for at least 35 years.*" There was no technical basis provided for this statement.

Design Life. DOE used a 35-year design life for the panel closure system,[1, 3] which equates to the projected operating period from the initial deposit of TRU wastes to the final closure of the repository.

III.C Realism of Design Criteria

<u>VOCs</u>. Results summarized in the report entitled *"Technical Evaluation Report for WIPP Room-Based VOC Monitoring."*[17] indicate that the highest carbon tetrachloride concentration measured in the ambient air of Room 2, Panel 2—which contained the waste stream of TRU mixed wastes with the highest VOC concentrations in the head space gas (based upon the measurement of head space gas in over 70,000 drums)—was three orders of magnitude below the associated room limit established by the HW permit. Measurements of carbon tetrachloride concentrations made at Station A for the same time period revealed that those concentrations were about a factor of 10 less than the limit set for Station A by the HW permit. With respect to the possibility that the wastes might contain significant quantities of VOCs that will be released after room or panel closure, the potential production of VOCs is also limited by the requirement that the waste containers must contain less than one percent by volume of liquids.[18] Given the basic volatility of the VOCs and the results of the head space gas analysis conducted to date, it is a reasonable conclusion that any liquids remaining in the waste container after disposal in WIPP do not contain significant quantities of VOCs. More likely, the liquids will be water, oils, or a mixture thereof.

Even if there were to be accidental releases of significant quantities of VOCs in a filled room during the period of waste disposal operations, the operation of the underground ventilation system would initially control potential worker and public exposure. This ventilation system, which is described in detail in Attachment M2 of the HW permit,[3] is designed to control potential airborne contaminants in the event of an accidental release or underground fire and requires each room to be isolated with the ventilation barricades cited above. It can thus be interpreted that the ventilation barricades are sufficient for worker protection from VOCs or other gaseous releases from disposed wastes, at least during the panel closure system's 17-month allowable construction period. This view is further supported by the results of the environmental monitoring programs for the WIPP that indicate the VOCs' concentrations at Station A are well below the allowable limits.[19]

This discussion illustrates that VOC limits established in the permit to design and evaluate panel closure systems were overestimated when weighed against actual conditions, and that the ventilation barricades are therefore sufficient for VOC control.

Gas Generation by Wastes. Three possible mechanisms for gas generation by the TRU wastes deposited in the WIPP have been identified:[20]

1) *Radiolysis*;
2) *Anoxic corrosion*, the chemical reaction of the carbon steel waste containers with any brine that might be present to produce mainly hydrogen gas; and
3) *Microbial reactions* with some of the organic waste constituents (e.g., cellulose).

The gas generation rate and the types of gases produced are dependent upon three major factors: 1) the amount of water (brine) available and its contact with the waste containers and the waste itself, 2) whether or not the atmosphere is oxic or anoxic, and 3) the presence of microbes. The documentation reviewed indicated extensive uncertainties with respect to the timing of brine inflow, the timing and extent of the contact of the brine inflow with wastes, the time after brine inflow and before gas generation would start, and the duration of gas generation.[20] As an indication of the scientific uncertainty relative to gas generation, the detailed design report for the panel closure system[16] suggests that gas-generation rates, due to microbial degradation, might range from 0.01 to 0.1 moles per drum per year, with methane comprising 70 percent of the gas. Using the estimate of 0.1 moles per drum per year, it was determined, as shown in *Figure 4*, that the potential for a methane deflagration and consequent pressure buildup would not occur for at least 20 years after panel closure.

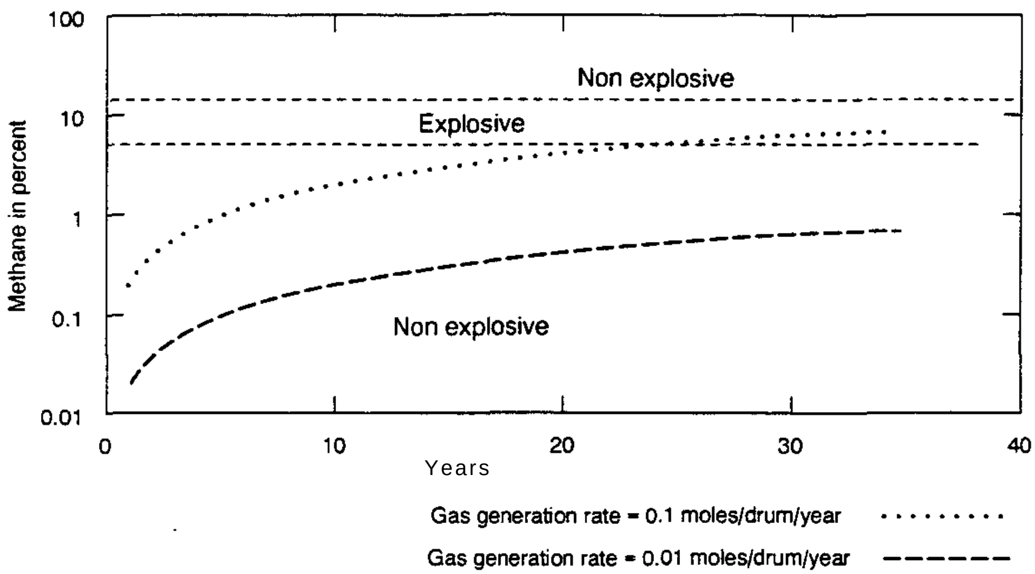


Figure 4. Methane concentrations in the waste panel over time (from Detailed Design Report for Operational Phase Panel Closure System 1996 – Reference 14).

This estimate appears to be based upon two key assumptions: 1) that the oxygen (O_2) concentration in the waste panel remained at 18 percent, and 2) that the biogeneration of methane would start within a short period of time (months at most) of panel closure. With respect to the O_2 concentration in the panel atmosphere, it would appear that if there was enough brine inflow to cause contact with large amounts of iron in the waste, that iron would rust—thereby depleting the O_2. As the O_2 concentration decreases, the concentration range of methane that is explosive narrows and more time is required to reach a methane concentration with explosion potential.[2]

The second assumption, which has a larger impact on the estimate of a potential explosion, is based upon two further assumptions: 1) the influx of sufficient brine into the waste panel to sustain the biogeneration after closure, and 2) the presence and survival of microorganisms necessary for the biogeneration. As indicated above, there are no data presented in the documentation reviewed for this report to indicate there will be any significant amount of brine inflow to the closed waste panel during the operating life of the WIPP.

In addition, the Appendix Barriers in the CRA[2] states that research conducted since the CCA was submitted indicates that biogeneration is not expected to begin in TRU wastes for approximately 7.2 to 7.4 years after humid or saturated conditions develop in the wastes. This information indicates that the estimate that an explosive condition could develop in 20 years based upon the assumption of 0.1 moles/drum/year gas generation is overly conservative. In fact, due to the fact that the very small volume of water in the waste (<1% by volume) is insufficient for development of either humid or saturated conditions in the drums—the slow rate of brine flow into the closed waste panel, the low humidity associated with brine due to the low vapor pressures, and the likelihood that the gas generation rate will be substantially less than 0.1 moles/drum/year—it is not unreasonable to assume that explosive conditions will not develop in the closed waste panel during the 35-year design life of the repository.

Salt Creep. Actual measurements taken in the repository indicate a salt creep of between 0.002 and 0.003 inches/day.[12] Extrapolating this estimate to the volume reduction due to salt creep expected in the eight rooms and connecting drifts in the panel, the design criterion is reasonable.

IV. CONCLUSIONS

1. The EPA decision to include a panel closure system of the type proposed by the DOE in the CCA is justified, but the requirement that it be the most robust of the four options presented with the added use of SMC is not scientifically supported.
2. The measured concentrations of VOCs in the TRU waste containers and Panel 2 indicate that a panel closure system as robust as the approved panel closure system or the proposed (WPC) design is not required for worker or public health protection from VOCs. In fact, it appears that nothing more than the ventilation barricades and maintenance of the underground ventilation system to keep it in good working order are required for VOC control.
3. One requirement for the panel closure system design is that the system withstand the effects of a large pressure increase (≥240 psi) that might be caused by generation of gas from stored waste during the 35-year operating life of the WIPP. This review has determined that :
    a. Experience to date has not shown gas generation rates approaching the upper estimate of 0.1 moles per container, (the design basis);
    b. There is no indication there will be an immediate or sufficient inflow of brine after panel closure to sustain even the low end of the estimated biogeneration rate;
    c. Even if there is significant brine inflow to a closed panel, the hydration of the brine with the MgO would retard any associated increase in humidity that may occur; and
    d. Research has shown that even with the presence of sufficient water/brine, biogeneration of methane would not commence until at least seven years following panel closure.

Therefore, the possible buildup of gas pressure in a closed panel is overestimated. Further, if only ventilation barriers are used during panel closure, there will not be any gas pressure buildup, since the barriers are not impermeable.

4. If permeability control is considered necessary to meet the requirements of 40CFR194, design studies supported by technical evaluations performed for DOE confirm that either the approved panel closure system or the WPC system design would provide the necessary control during the operating period of 35 years. Simpler panel closure systems such as bulkheads may also fulfill this requirement.

5. The currently considered panel closure system designs assume a 35-year functional life. Given that only the early panel closures are required to have a functional life approaching 35 years, DOE's originally proposed approach to adopt a design meeting lesser demands for the later panels is valid.

6. Replacement of the approved panel closure system design with a more constructible design is desirable and perhaps essential, as it will reduce safety and health risks to workers.

7. The WPC system design is more than adequate to meet requirements, but close monitoring of the mortar emplacement quality is necessary to ensure the design criteria for permeability is met if that criteria continues to be used. Also, the design reports did not demonstrate that the 100 feet of salt backfill can be uniformly placed against the drift ceiling, thereby preventing the formation of a more highly permeable flow channel due to non-uniform salt compaction by salt creep.

8. The utility of the 100-foot-long salt backfill component of the WPC system is questionable for most panels, given that its contribution is not expected to come into play for 30 years, and the potential for a methane explosion is not projected to occur for at least 18 years (and most probably not for 30 years—if at all).

9. The collection and analysis of tens of thousands of headspace gas samples and the monitoring conducted at the repository have documented that concentrations of VOCs in the TRU waste are so low that the underground ventilation system requirements provide sufficient control. However, current monitoring programs cannot provide the data necessary to effect a good understanding of the physical and chemical reactions within the waste containers following their emplacement in the repository or the changes, such as brine inflow, that are projected to occur in the filled rooms

and panels. This lack of actual and current data on the behavior of the wastes and the filled rooms and panels inhibits the design of the most cost-effective panel closure.

V. RECOMMENDATIONS

It is recommended that:

1. The need for and type of panel closure system should be reevaluated based on the full suite of actual data and measurements of the waste and repository conditions relevant to panel closure as well as on latest research results regarding waste and repository behavior under the range of conditions possible after panel closure. This reevaluation should start with the simplest closure system (i.e. brattices to isolate filled panels from repository ventilation) and progress until design criteria are met.
2. Concurrent with the reevaluation of the need for and type of panel closure system, the Performance Assessment should be re-run for all alternatives considered—starting with the "ventilation barrier only" panel closure system—to determine what alternatives will suffice for compliance with 40CFR194 requirements. This determination would provide the essential documentation that would enable the EPA to approve any proposed alternative to the one currently approved.
3. The CBFO should press for approval to expand the current monitoring programs, including monitoring closed rooms and panels. The decision for such approval should be made as soon as possible—preferably before the next panel is closed—because data collected after room and panel closure over the duration of a monitoring program will become important factors in determining what type of panel closure system is necessary for final closure of filled panels.
4. Since it has been suggested that WIPP operating life may be extended up to perhaps 100 years.[17] It is recommended that CBFO evaluate what impact this change might have on panel closure requirements, especially considering Conclusion 3, above.

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ADDITIONAL REFERENCES:

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   DOE proposed seven enhancements to the approved panel closure system design following its adoption. Environmental Evaluation Group (EEG) was contracted to evaluate these enhancements. EEG contracted with two experts in the field to provide technical reviews and recommendations: Dr. John Abel, a mining engineer from Golden, CO and Dr. D.R. Morgan, a materials engineer from Vancouver, British Columbia, who agreed with five of the enhancements, conditionally approved a sixth one, and recommended opposing one. EEG accepted these conclusions. However, in the meantime, DOE withdrew the proposed enhancements recognizing that the subject would be revisited later. The EEG-82 report was thorough and informative, but since its relevance is now of little value, a detailed review of this report was not conducted.

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