Assessing Engineered Systems in Geologic Repositories: WIPP

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Frank Hansen, PhD.
Sandia National Laboratories
Albuquerque New Mexico
WIPP: A Solution of a National Problem
Waste Isolation Pilot Plant
Chronology 1975-2009

1975

1979

2000
WIPP Underground Layout
Bedded Salt Was Chosen for the Siting of the US Defense Nuclear Wastes

- Salt can be mined easily
- Salt has a relatively high thermal conductivity
- Wide geographic distribution (many potential sites)
- Salt is plastic *
- Salt is essentially impermeable *
- Fractures in salt are self healing *
- Salt has existed underground for millions of years *

* Attributes of Natural Barrier
EPA defines barriers as “any material or structure that prevents or substantially delays movement of water or radionuclides toward the accessible environment”

1. Salt – the Most Important Barrier
2. Shaft Sealing System
3. Panel Closure System
4. Magnesium Oxide Engineered Barrier
5. Materials Interaction

Discussion will reverse the order
Waste Package Performance

- HLW waste package material
- Materials Interface Interaction Tests
- Simulated RH and CH TRU corrosion/durability
- BAMBUS II
- Potash Basin Experience (1930’s)
WIPP Disposal Room Evolution
WIPP Room Evolution at Time=0 years
WIPP Room Evolution at Time=12 years
WIPP Room Evolution at 1000 years

Time - 1000 years +

Anhydrite b

MB139

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Waste Package Interactions
MgO Engineered Barrier

• MgO will act as an engineered barrier in the WIPP by decreasing actinide solubilities.

• Control $P_{\text{CO}_2}$ and pH within favorable ranges.

• Only engineered barrier recognized by EPA.

• Ongoing lab studies imply MgO will effectively remove $\text{H}_2\text{O}$ and $\text{CO}_2$. 
Option D Panel Closure System

<table>
<thead>
<tr>
<th>Undisturbed halite</th>
<th>Anhydrite layers</th>
<th>Disturbed rock zone (DRZ)</th>
<th>Healed DRZ</th>
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Waste Panel | Explosion Wall | Open Drift | Concrete Monolith | Open Drift
Proposed Panel Closure System
Shaft Seal System Design Guidance

- Limit hazardous constituents reaching regulatory boundaries
- Restrict groundwater flow through the sealing system
- Use materials possessing mechanical and chemical compatibility
- Protect against structural failure of system components
- Limit subsidence and prevent accidental entry
- Utilize available construction methods and materials
Shaft Sealing System

Depth
0
17 m

Near-surface Units
1. Earthen fill
2. Concrete plug
3. Earthen fill

Dewey Lake Redbeds

162 m

Rustler Formation
4. Rustler compacted clay column
5. Concrete plug
6. Asphalt column
7. Upper concrete-asphalt waterstop

256 m

Salado Formation
8. Upper Salado compacted clay column
9. Middle concrete-asphalt waterstop

655 m

Salado Formation
10. Compacted salt column
11. Lower concrete-asphalt waterstop
12. Lower Salado compacted clay column
13. Shaft station monolith
Shaft Seal System Conclusions

- The WIPP shaft seal system effectively limits fluid flow within the seal system.
- The salt column becomes an effective barrier to gas and brine migration by 100 years after closure.
- Long-term flow rates within the seal system are limited.
Natural Barrier – It’s the salt

Salt formations are used for disposal at WIPP.

Germany has several disposal facilities for toxic and radioactive waste in salt:

- Herfe-Neurode
- Morsleben
- Asse

Salt is an attractive disposal medium. Additional heat from the disposed waste can accelerate encapsulation. Salt provides a viable disposal option for heat-generating nuclear material, such as fission products resulting from recycling fuel rods.
Salt Behavior is well Understood
Disturbed Rock Zone around a Disposal Room

Undisturbed Zone:

\[ \sqrt{J_2} \leq 0.27 \cdot I_1 \]
Thermomechanical Response of Salt

• Thermal activation will increase creep of the salt
• Plastic creep deformation would enhance room closure and encapsulation
• WIPP’s original mission included defense HLW and spent fuel
• Thus, there is a considerable amount of information on heat-generating waste in a salt repository
Temperature Effect on Salt Deformation

All tests performed at a deviatoric axial stress of 10 MPa
Major Tests in the WIPP

Field Tests:
A. 1.8 W/m² Mockup
B. CILW Overtest
C. Intermediate Scale Rock Mechanics and Permeability Tests
D. Mining Development
G. Geomechanical Evaluation
H. Heated Pillar
J. Simulated CH TRU Tests (Wet) and Materials Interface Interaction Test (MIT)
L. Plugging and Sealing, Waste Drum/Backfill Tests
M. Small Scale Seal Performance Tests
T. Simulated CH and RH Tests
Q. Circle Breakaway Tests
V. Air Intake Shaft Performance Tests

Salt and Interbed Permeability and Brine seepage tests at numerous locations

Note: Not to Scale

Future
Axisymmetric Test with Insulation

Room H
18 W/m² Thermomechanical Test

• “A” Rooms
Measured vs. Predicted Room Closure
Summary – It’s the salt

• The concept of disposal of heat generating nuclear waste in salt has been considered viable for many years
• Thermal acceleration of plastic creep deformation can positively affect encapsulation
• A significant number of full-scale field demonstrations of heater tests in salt have been completed
• Salt remains an attractive medium for disposal of nuclear waste
ReCap

• Several barriers engineered for WIPP
• No performance credit for waste package
• MgO engineered barrier (assurance)
• Panel closure performance implication
• Shaft seal system
• It’s the salt

Next: Salt thermal studies indicate balance of local and far field heat provides considerable volume for disposal of large volumes of other possible inventories (GTCC).