Brine Availability Test in Salt: THMC Simulations of a Heated Borehole in Salt

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Spent Fuel & Waste Disposition

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Brine Availability Tests in Salt (BATS)

Storing heat generating nuclear waste in salt is being investigated at WIPP
Is A Salt Repository the Answer?

- Salt is an attractive geological medium due to its extremely low permeability, self-sealing ability, and high thermal conductivity.

- However, questions remain regarding brine origin, availability, and chemistry during the heating of salt.

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*Erickson and Dials, RadWaste Solutions, Jan.-Apr., 24-34, 2011.*

*Fluid inclusions migrating under a thermal gradient - Carter and Hansen, Technophysics, 93, 1983.*
Water Sources in Salt

- Water sources in bedded salt:
  - **Intracrystalline** (brine inclusions)
  - **Intercrystalline** (e.g., mobile “pore fluid”)
  - Water associated with clay minerals and polyhalite
- Water may be liberated from brine inclusion migration and clay dehydration (above 65°C)
**Salt THMC Couplings**

- **Deformation** \( F(temperature, stress, time, saturation) \)
- **Vapor pressure lowering** \( F(capillary pressure, salinity) \)
- **Porosity** \( F(dissolution, precipitation, stress, strain) \)
- **Thermal conductivity** \( F(temperature, porosity, saturation) \)
- **Permeability** \( F(porosity, saturation) \)
- **Capillary pressure** \( F(porosity, saturation, temperature) \)
- **Water vapor diffusion** \( F(porosity, saturation, temperature) \)
- **Clay dehydration** \( F(temperature) \)
BATS: Phase 1s (Shakedown)

Tests Began in July 2018 and were complete in May 2019
PHASE 1s: TEMPERATURE RESULTS

Heater Block

IR Heater

![Graph showing temperature results for Heater Block and IR Heater](image)

Temperature at Observation Borehole (°C)

**750 W - IR Heater**

**260 W - IR Heater**

**Step Test - Heater block**

**120 °C - Heater block**

Time (Days)
PHASE 1S: FEHM MODEL

Highly refined 3D Mesh

20m x 20m x 10m

1,003,995 total elements
**Phase 1S: Pressure Distribution**

Long term simulations used to predict initial reservoir pressure

![Pressure Distribution Diagram](image)

- 1982 Drift excavated
- 2012 Borehole Drilled
- 2018 Shakedown test begins
SHAKEDOWN: HEATER BLOCK

- Heater block makes minimal contact with salt and is buffered by air.

Contact with salt
SHAKEDOWN: IR HEATER

IR heater is fully coupled to salt

260W IR Heater

750W IR Heater
**WATER PRODUCTION**

- Dry nitrogen carries out water vapor
- Water mass measured by Drierite mass change

Intact Salt permeability: $1e^{-21} \text{ m}^2$

DRZ permeability: $1e^{-18} \text{ m}^2$

Background Pressure: 12 Mpa
BATS: Phase 1

Brine Availability Test in Salt at WIPP (BATS) Phase 1

Monitoring brine distribution, inflow, and chemistry from heated salt using geophysical methods and direct liquid & gas sampling.

Heater turned on January 2020
BATS: PHASE 1 BOREHOLE PATTERN

BOREHOLE HEATER TEST CONFIGURATION (FINAL)

- T = Temp Only Holes
- AE = Acoustic Emissions
- SL = Seal
- D = D2O + Tracer Source
- E = ERT Electrodes
- F = Fiber Optic (T and/or Strain)
- SM = Sampling
- HP = Heater and Packer

Diagram details include borehole diameters and lengths, with various symbols and labels indicating test configuration and parameters.
BATS: Phase 1 Layout
PHASE 1: PRESSURE DISTRIBUTION

- 7 years of open drift
- 5 days of open boreholes

Slice 2 m into the drift face
PHASE 1: TEMPERATURE PREDICTION

$$K_T(T) = K_{T\cdot300} \left(\frac{300}{T}\right)^{1.14}$$

Halite

$$K_{T\cdot300} = 5.4 \frac{W}{mK}$$

Rock Salt

$$K_{T\cdot300} = 4.5 - 5.5?$$

Heated Borehole

Rock Salt

$$K_{T\cdot300} = 5.15$$
PHASE 1: OTHER OBSERVATIONS

Temperature

Strain

Isotopes

Electrical Resistivity

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