First-Round Testing of the Brine Availability Test in Salt (BATS) at the Waste Isolation Pilot Plant (WIPP)

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Abstract

The Brine Availability Test in Salt (BATS) is a field heater test being conducted in the bedded salt formation at the Waste Isolation Pilot Plant (WIPP) near Carlsbad, NM. BATS is focused on exploring brine availability as part of a wider investigation into the disposal of heat-generating radioactive waste in salt. Brine has the potential to transport radionuclides, corrode waste forms and packages, reduce criticality, and pressurize porosity to resist closure through salt creep. In BATS, two identical arrays of horizontal boreholes were constructed in an experimental drift, 650 m below ground at WIPP. In each array, 13 observational boreholes were installed around a central borehole. One of the two array was heated, and the other array was left at ambient temperature. During the first heating phase (January to March 2020), the 750 W heater ran for 4 weeks. The central boreholes included dry nitrogen gas circulation behind a packer. The gas stream removed moisture which flowed into the boreholes. The gas stream was analyzed in-drift for stable water isotopes using a cavity ringdown spectrometer and gas composition using a quadrupole mass spectrometer. The satellite boreholes in each array included numerous thermocouples, electrical resistivity tomography (ERT) electrodes, acoustic emissions (AE) piezoelectric transducers, distributed temperature and strain fiber optics, and a cement seal exposure tests (both sorel and fly-ash base concretes). Cores from the boreholes were X-ray CT imaged for mineralogical and fracture distribution. We present an overview of the first phase of the test, and illustrate key data collected during the first heating cycle. Follow-on tests in the same boreholes will include gas and liquid tracer tests and additional packer-based gas permeability testing. New boreholes for the next round of BATS in 2021 are being planned.

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WIPP Overview

We present the background for and data from the 2020 borehole heater test experiment called the Brine Availability Test in Salt (BATS). The test is funded by the DOE Office of Nuclear Energy (DOE-NE) and is located underground at the Waste Isolation Pilot Plant (WIPP), a DOE Office of Environmental Management (DOE-EM) site. BATS is a task in the DECOVALEX-2023 international model validation exercise.

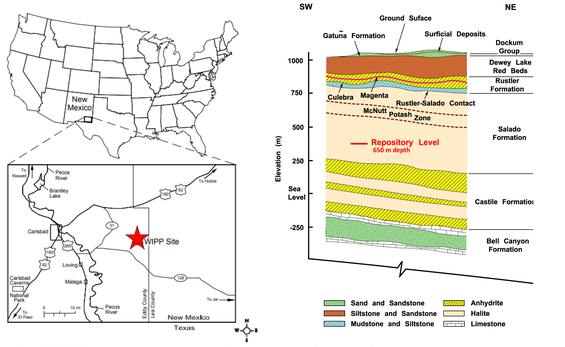


Fig 1: WIPP location and Geologic Cross-Section

DOE-NE is investigating the effects of elevated temperatures on salt relevant to the long term safety of disposing of high-level radioactive waste. DOE-NE is investigating generic (i.e., non site specific) disposal concepts in salt, crystalline, and argillite rocks. Salt has favorable properties for heat-generating radioactive waste disposal.

WIPP is a DOE-EM facility for disposal of low-level transuranic defense waste (Fig 1). DOE-EM is providing access to WIPP underground experimental areas in bedded salt for the heated DOE-NE BATS experiment (Fig 2).

Fig 2: Photo and drawing of BATS test drift at WIPP

Motivation

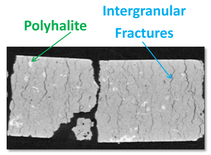
We seek to understand *brine availability* in salt at elevated temperatures, which depends on:

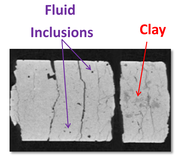
- Amount and distribution of brine in salt
- Distribution and evolution of transport pathways in salt

Bedded salt has 4 main types of brine:

1. Disseminated clay
2. Intragranular fluid inclusions
3. Hydrous minerals (e.g., polyhalite)
4. Intergranular brine

These brines are identified in X-ray CT images from NETL. Each type of brine reacts differently to pressure and temperature changes.





10.1 cm diameter core CT data

Field Test Borehole Configuration

BATS consists of two arrays of horizontal boreholes (heated and unheated) completed in salt. Each array (Fig 3) has boreholes for monitoring:

- Temperature via thermocouples and fiber optics
- Electrical resistivity tomography (ERT) (**MR005-05**)
- Acoustic emissions (AE) (**MR002-0004**)
- Cement / salt / brine seal interactions (**MR005-03**)
- Brine composition
- Distributed strain and temperature sensing via fiber optics

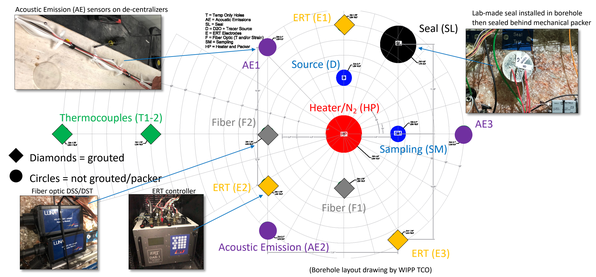


Fig 3: Layout of horizontal boreholes in each array

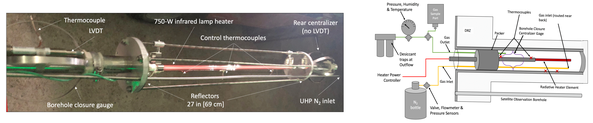


Fig 4: Photo and diagram of heater showing borehole closure gauge, heater, and thermocouples

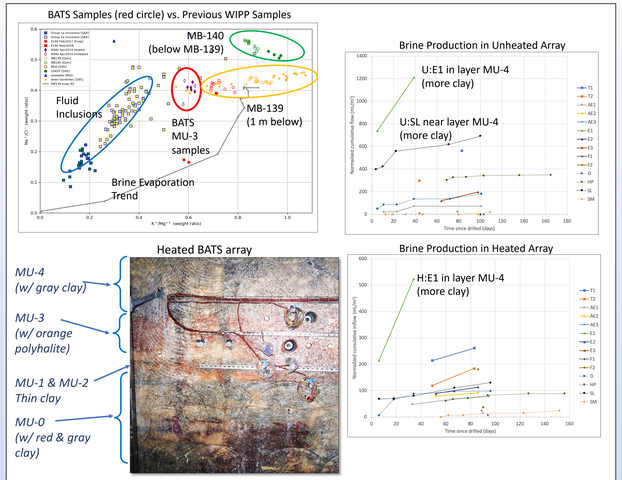


Fig 5: Brine production from instrument holes before completion, brine chemistry, and geology Map Units (MU)

Preliminary Data

Brine production (Fig 5) in boreholes after drilling (before grouting boreholes during instrumentation installation) shows a significant variability in production between boreholes, but consistent chemistry. The two highest-elevation boreholes (E1 in both arrays, and SL in unheated) produced the most brine, due to their location in MU-4, which has more clay. The boundaries between layers are heterogeneous at the cm-scale (see image).

BATS 1a was a heating experiment run January-March, 2020 (Fig 6). Follow-on tests (BATS 1b-1c) are scheduled will perform tracer tests in these same boreholes. BATS 2.0 will be conducted in new boreholes.

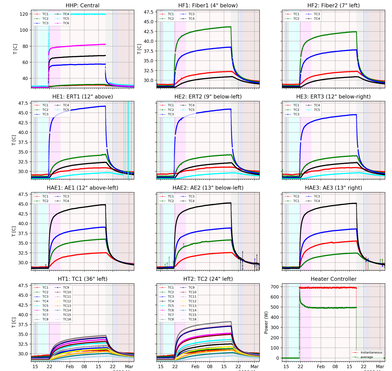


Fig 6: BATS 1a Temperature response due to heating

During heating and cooling, water was removed from the heated and unheated HP boreholes via a stream of dry nitrogen (Fig 4 & 7). The gas stream was monitored for water isotopes and gas composition via in-drift spectroscopy.

At heater shutdown, a leak began in the unheated D packer (source borehole). The leak allowed packer inflation gas (N_2) to circulate through the salt, as the gas flowed between boreholes. This N_2 swept additional water from the formation into the HP borehole. The impacts of this are being investigated.

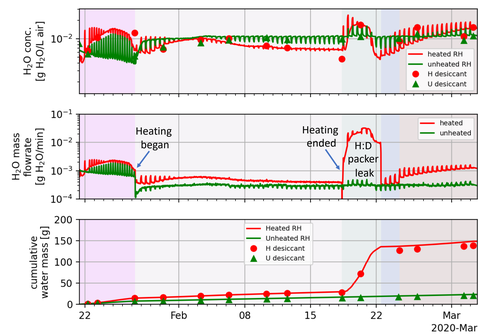


Fig 7: Water production during BATS 1a

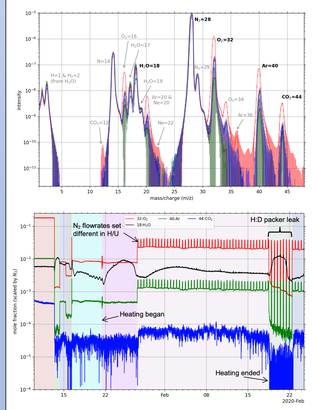


Fig 8: BATS 1a gas composition

The gas streams from the HP boreholes were analyzed via in-drift spectroscopy (Fig 8). This data showed typical atmospheric gas components, with concentration inversely proportional to N_2 flowrate, indicating a slow leak of atmospheric air through the formation/packer system.

Analysis of BATS 1a data continues and follow-on tests are being planned (1b & 1c), and collaborative efforts to model the data are underway (DECOVALEX-2023).

Reference:

Kuhlman, Millis, Jayne, Matteo, Herrick, Nemer, Heath, Xiong, Choens, Stauffer, Boukhalfa, Guiltinan, Rahn, Weaver, Dozier, Otto, Rutqvist, Wu, Hu, Uhlemann, Wang, 2020. *FY20 Update on Brine Availability Test in Salt*. (107 p) SAND2020-9034R, Sandia National Labs.