U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

PRESENTATION TO
THE NUCLEAR WASTE TECHNICAL REVIEW BOARD

SUBJECT: PROTOTYPE FIELD TESTS OF THE NEAR FIELD ENVIRONMENT

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Purpose is to evaluate the ability to characterize near field environment

- Evaluate technical feasibility of defining near field hydrothermal and geochemical environment during field testing
  - measurement technique performance

- Provide in situ data to improve understanding of conceptual models for near field environment

- Develop Quality Assurance technical procedures
  - evaluate under realistic conditions
Rock was perturbed by a heating & cooling cycle

- Heat load approx. = 1.0-1.2 kW per meter of heater length
- Boiling region diameter \( \sigma \): approx. 1.4 meters
- Heater on for 195 days, 128 days heating, 68 days of power ramp-down
- Cooling highly accelerated (compared to a spent fuel waste package)
Plan view of test region

2 meters

Heater

- Changes in moisture content (geophysics), removable thermocouples
- Gas pressure, humidity / suction, temperature

temperature
Various sensors monitored hydrothermal behavior of the rock

- Temperature -- thermocouples (approx. 120)
- Moisture content -- dielectric, neutron, and gamma density logging
- Steam pressure -- air pressure transducers
- Matrix pore pressure -- psychrometers, microwave resonant circuits, capacitance sensors
- Rock permeability -- air injection tests
- Moisture invading heater borehole -- condensation trap
- Fracture mapping -- core logging, borehole tv
- Atmospheric pressure -- barometer
Measurements confirmed elements of the conceptual model

- Dry region around heater, drying increases toward heater
- Saturation "halo" next to dry region and later dries as rock gets hotter
- Radius of dry region matched prediction of 0.6 - 0.7 m; total change is .16 g/cc
- Fractures have measurable effect on drying/condensation front; re-wetting primarily along fractures
- Measured temperatures close to predictions; slight fracture effect where boiling occurs
There were some surprises

- Below heater rock dried faster as temperatures increased
  - gravity, fractures

- Above heater rock rewetted faster as temperatures decreased
  - steeper moisture gradient, gravity

- Halo of increased saturation differs from predictions
  - due to high initial saturation? & to lack of wetting curves?

- Slight increases in rock permeability

Several measurement problems: corrosion, inadequate calibration process, inconsistent results
Data from several boreholes are combined to form radial profiles.
Drying front advanced faster below heater than above

Full power phase, 70 days after start of heating
Rock above the heater re-wetted faster than below

Heater off, 301 days from start of heating

[Graph showing moisture content changes with radial distance]
Fractures increase the rate of re-wetting

Borehole NE-2A, ramp-down phase, changes relative to last day of heating
Capillary condensation, dripping and imbibition served as re-wetting mechanisms.
Predicted and measured radial profiles are different.
Side view showing thermocouple locations
Heat transfer by conduction and by mass transport

Temperatures after 2.5 months of heating

- Fractures affecting mass transport and heat transfer
- Heat transfer by conduction

boiling point

Natural log of radial distance
Some regions remained at boiling point for a long time
Liquid may be shed from top to sides and bottom of boiling region
Predicted and measured temperatures are very close.
Heating changed air permeability near heater

Fractures mapped along heater borehole

Gas permeability (Darcy)

Preheat values

Post heat values

Location of heater element

depth (m)