THE COLD-TRAP PROCESS AND ITS EFFECT ON MOISTURE DISTRIBUTION AND CHEMISTRY OF WATER IN DRIFTS

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What is "Cold Trap" Process ?

- The cold-trap process in tunnels involves:
  - Evaporation from warmer areas and condensation on cooler or hygroscopic surfaces
  - Movement of vapor driven by thermal gradients
  - Continuous source of moisture from mountain scale vapor transport and ambient percolation
- Relevant literature topics
  - Natural convection in horizontal eccentric cylinders
  - Condensation in pipes, boundary layer transfer

The Cold Trap and Yucca Mountain

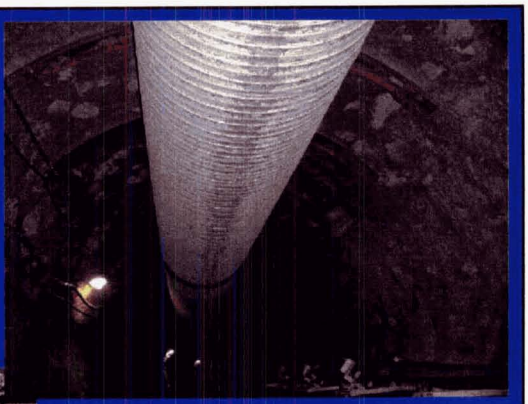
The cold-trap process describes a mechanism for in-drift water movement

Why is it important?

- Provides localized liquid water that may contact drip shields and waste packages leading to corrosion
- After possible waste package failure, liquid water provides a pathway for radionuclide transport
- Occurrence and effect varies

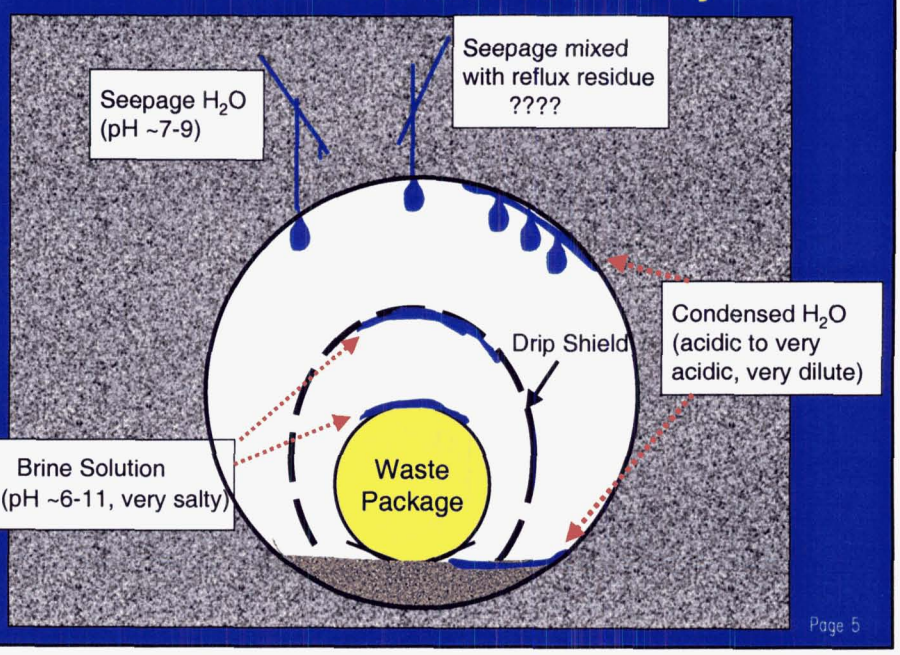
Passive Test

- Possible components of water in Passive Test in Cross-Drift tunnel at Yucca Mountain
  - condensation
  - seepage



- Condensation surfaces
  - rock bolts, wire mesh, conduit, infrastructure, invert, drip shield
- Dripping locations
  - drip shield, waste package, invert

Water Sources and Chemistry



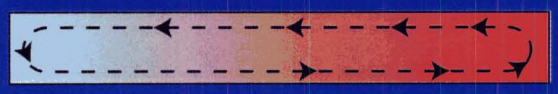
Goals of Investigation

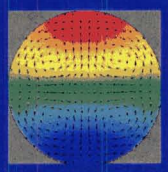
To determine the importance of H_2O to drip shield/waste package lifetimes and develop experiments and models to estimate the:

- quantity of condensed H_2O as a function of time and location in the repository setting
- chemical compositions of condensed H_2O reacted with natural and engineered materials (i.e. rock bolts, wire mesh) at various temperatures
- range of H_2O compositions resulting from mixtures of brine, seepage and condensed waters

Conceptual In-Drift Flow Patterns

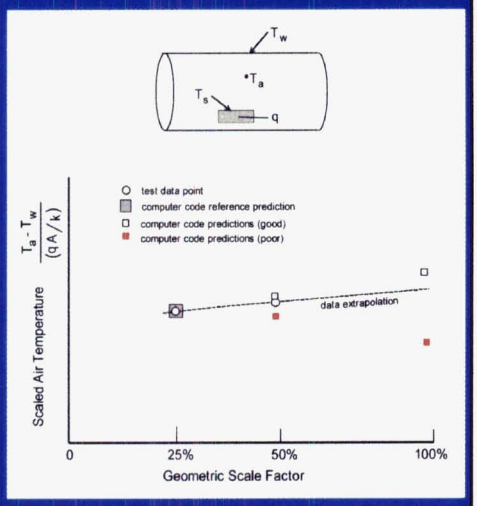
- Interplay between
  - strong local temperature variations leading to prominence of cross-sectional flow patterns
  - strong large-scale temperature variations leading to prominence of axial flow





Thermal Scaling

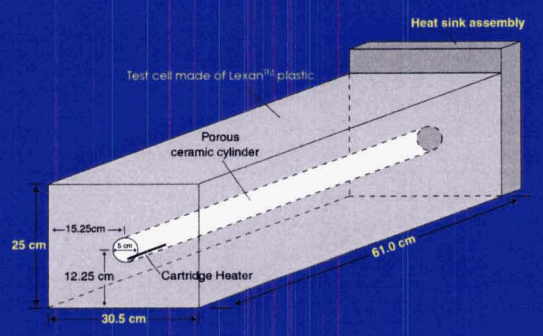
- Maintain temperature difference and assume heat transfer coefficient is constant
  - T_a for scaling is problematic
  - Heat transfer not constant across scaling
- Scaling Issue: Grashof number estimation is critical for flow, must get flow correct to get condensation correct
- Confidence gained if computer simulations adequately compare to test results at 2nd scale

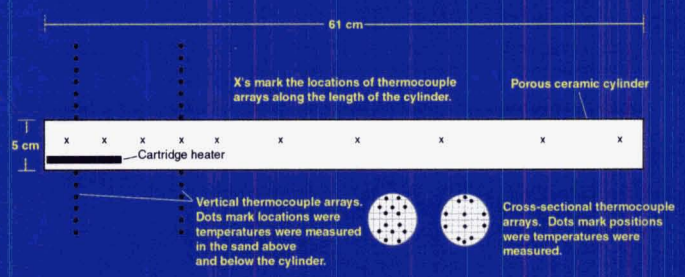


Condensation Model Approaches

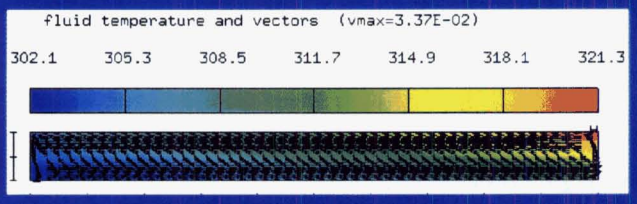
- Simple approach
  - drop all condensate out at cold end
- Physically realistic approach
  - drop condensate out when dew point reached
  - diffuse and convect water to condensation point as condensation occurs

Laboratory Model





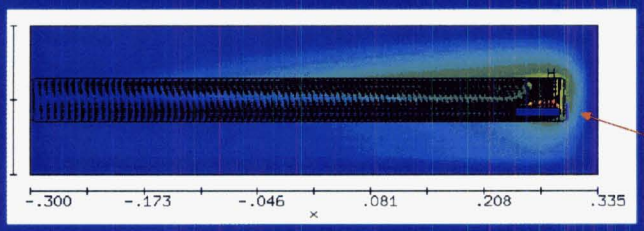
Air Flow Pathways and Temperature Profiles Modeled by FLOW-3D



Insulated boundary at drift

Effects of:

- conduction
- radiation
- boundary condition
- convection
- latent heat transfer

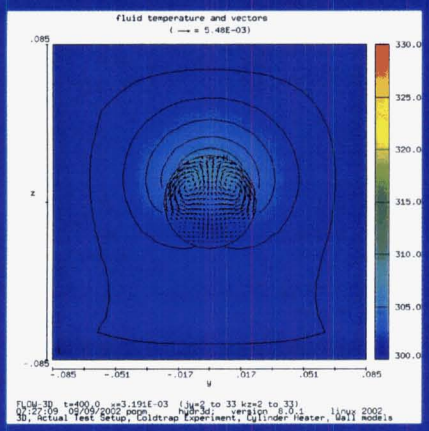


Heater Temp not displayed

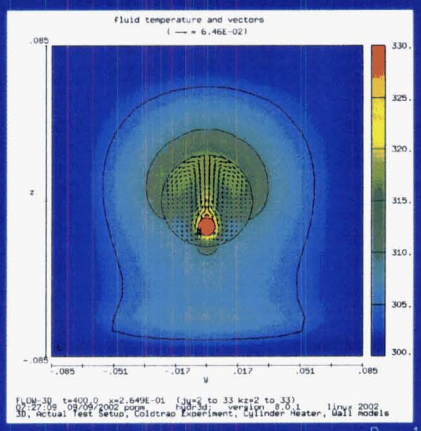
Wallrock (sand) included

Typical Cross-Sectional Views Modeled by FLOW-3D

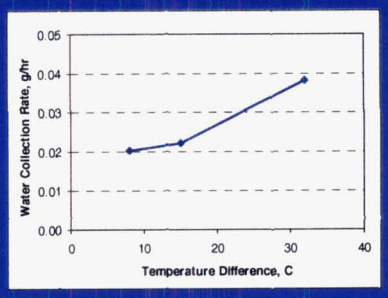
Mid-Tunnel Position



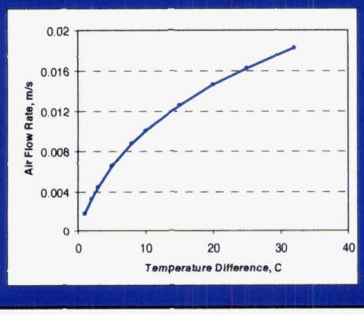
Above Heater

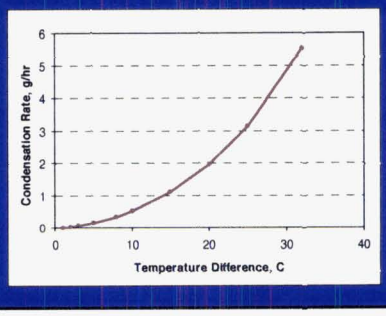


Measured Condensation Flux



Calculated Air Flow and Condensation Flux





Discrepancy Between Models

- Analytical solution assumes all condensation occurs on cold wall
  - Based on air flowlines from CFD simulations, only a small fraction may condense on the cold wall
- Note: Modules will have to be added to CFD codes (e.g., FLUENT, FLOW3D) to simulate cold trap

Summary

- Cold trap process is a mechanism for water to contact waste packages in cooler zones and edges of drifts
  - modify chemistry of solutions
  - potential to accelerate re-wetting of invert and drift shadow
- Modeling results based on laboratory experiments useful for:
  - understanding linked physical processes
  - developing methods for larger-scale model
- Large uncertainty caused by:
  - lack of understanding physical processes
  - lack of supporting data