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

PRESENTATION TO
THE NUCLEAR WASTE TECHNICAL REVIEW BOARD

SUBJECT: EFFECTS OF REPOSITORY DEVELOPMENT

PRESENTER: DALE G. WILDER

PRESENTER'S TITLE AND ORGANIZATION: TECHNICAL AREA LEADER,
NEAR-FIELD ENVIRONMENTAL CHARACTERIZATION
LAWRENCE LIVERMORE NATIONAL LABORATORY
LIVERMORE, CALIFORNIA

PRESENTER'S TELEPHONE NUMBER: (415) 422-6908

REGISTRY HOTEL, DENVER, COLORADO
JUNE 25-27, 1991
Emphasis of Presentation

- Update of overview presented December 11-12, 1989 Information
- Disturbed Zone Characterization
- Repository/emplacement effects-design options
Update

- Physical Effects of WP Emplacement on the Environment
  Advances in hydrologic & chemical understanding
- Laboratory and Field Evidence for Physical and Chemical Effects
Summary 1989

- Modeling Activities successfully describe hydrological, & geochemical behavior of a range of laboratory and field systems
- Comparisons between model predictions, and laboratory and field studies identify important data and model needs
- Future work will concentrate on these areas, and on model validation
Rock-Water Interaction

<table>
<thead>
<tr>
<th>Rock</th>
<th>Water</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topopah Spring Tuff</td>
<td>J-13 concentrated</td>
<td>90-350°C</td>
</tr>
<tr>
<td>devitrified</td>
<td>J-13</td>
<td>~100 bars</td>
</tr>
<tr>
<td>Vitric</td>
<td>distilled</td>
<td>60-304 days</td>
</tr>
<tr>
<td>zeolitized</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Aqueous SiO2 activity plays key role in paragenesis of secondary minerals
- Diagenetic sequence of minerals & textures at Yucca Mountain are reproduced in experiments
- Zeolites produced contain cation compositions in fair agreement with ion exchange model added to EQ3/6
Cation-exchange modeling examples: Comparison of predicted with experimental isotherms

(a) Cs

(b) Sr

EQ3 prediction

Experimental data
Characterization of Altered (Disturbed) Zone

- Disturbed zone is a significant portion of the rock
- DZ is important to WP Performance
- DZ influences the Source Term
Interactions & radionuclide releases
and transport mechanisms
Movement of Water in Fractures
2 hour contaminated pulse followed after 30 days by a 4 hour clean pulse
2 hour contaminated pulse followed after 30 days by a 4 hour clean pulse

Permeability increased by 1000 —— diffusion dominated by imbibition
Effects of repository development and waste emplacement
Saturation of Rock around SF Boreholes
an example of changing environment with time
Vertical Temperature Profiles

- 1000 yr
- 400 yr
- 100 yr
- 50 yr

Boiling isotherm

Repository level

Water table

Temperature (°C)

Depth (meters)
Hydrology scientific output developed for design and performance assessment: water quantity
Hydrology scientific output developed for design & performance assessment: water quantity
Cumulative flow volumes

95% Design values

Flow (l/sq-m/yr)

% of repository horizon

Pre-emplacement

Post-emplacement to
300 yrs
0 l/yr/borehole

1000 yrs

10000 yrs

Pre-emplacement & post-10,000 yrs.
< 5 l/yr/borehole
Conclusions

Preliminary Design Bases:

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Leakage Rate (l/yr/borehole)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-emplacement</td>
<td>&lt; 5</td>
</tr>
<tr>
<td>Post-emplacement (~5 yrs) to 300 yrs</td>
<td>0</td>
</tr>
<tr>
<td>300-1000 yrs</td>
<td>0 to &lt; 3</td>
</tr>
<tr>
<td>1000-10000 yrs</td>
<td>&lt; 3 to 5</td>
</tr>
<tr>
<td>&gt;10000 yrs</td>
<td>&lt; 5</td>
</tr>
</tbody>
</table>
## Conclusions

### Preliminary Design Bases:

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Water Flow Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-emplacement</td>
<td>&lt; 5 l/yr/borehole</td>
</tr>
<tr>
<td>Post-emplacement (≈ 5 yrs) to 300 yrs</td>
<td>0 l/yr/borehole</td>
</tr>
<tr>
<td>300-1000 yrs</td>
<td>0 to &lt; 3 l/yr/borehole</td>
</tr>
<tr>
<td>1000-10000 yrs</td>
<td>&lt; 3 to 5 l/yr/borehole</td>
</tr>
<tr>
<td>&gt;10000 yrs</td>
<td>&lt; 5 l/yr/borehole</td>
</tr>
</tbody>
</table>
Initial Power Densities for Various Ages of Spent Fuel

<table>
<thead>
<tr>
<th>age (years)</th>
<th>10</th>
<th>20</th>
<th>40</th>
<th>60</th>
<th>80</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAPD (kW/acre)</td>
<td>73</td>
<td>56</td>
<td>39</td>
<td>29</td>
<td>23</td>
</tr>
<tr>
<td>APD (kW/acre)</td>
<td>60</td>
<td>46</td>
<td>32</td>
<td>24</td>
<td>19</td>
</tr>
</tbody>
</table>

based on spacing of 15 feet for vertical emplacement according to SCP-CDR
Mean radius of dry-out volume per emplacement drift is dependent on the age of the spent fuel at time of emplacement.
The fracture system sheds condensate due to a combination of: (1) vapor flow away from the heat source and (2) gravity-driven liquid flow.
Under hydrothermally perturbed conditions, boiling will mitigate episodic fracture flow from reaching the waste package (for up to 1000 years for a repository heat loading rate of 57 kw/acre) (Buscheck and Nitao, 1991)
Engineered backfill with high moisture sorbing material (e.g. crushed nonwelded PTn tuff) will mitigate episodic fracture flow from reaching the waste package (Buscheck and Nitao, 1991)
A "hydrothermal umbrella" is established along each of the emplacement drifts due to condensate being shed off of the sides of the boiling zone.
A 1-hour contaminated pulse followed after 0 days by a 4-hour clean pulse. Permeability increased by 1000 --- diffusion dominated by imbibition.
Day 4
End of 4 day release

Day 30
After 4 days of release, 4 more days of clean stream, and 12 days of rest
Post-emplacement Saturation Conditions around borehole of typical Spent Fuel Canister

Note: From Cove 3
0.1 mm/yr recharge
8.6 yr old spent fuel
25 yrs after emplacement

Direction of moisture movement induced by saturation gradient

Distance from W.P. emplacement borehole

Ambient

86%

0%
Yucca Mountain Matrix Saturation conditions as Currently Understood

Design Envelope

Bounding

Expected

% Occurrence

Matrix Saturation - %

30% 46% 65% 84% 95%
Prototype experiment of fracture-matrix flow

First episodic event: wetting front after 62 minutes of ponded conditions using blue dye tracer
Characterization of Altered (Disturbed) Zone

- Disturbed zone is a significant portion of the rock
- DZ is important to WP Performance
- DZ influences the Source Term
The disturbed zone is an important component of the total system.