YUCCA
MOUNTAIN
PROJECT

Studies

Commercial Spent Fuel Tests at ANL

Presented to:
CLST Appendix 7 Meeting

Presented by:
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U.S. Department of Energy
Office of Civilian Radioactive
Waste Management

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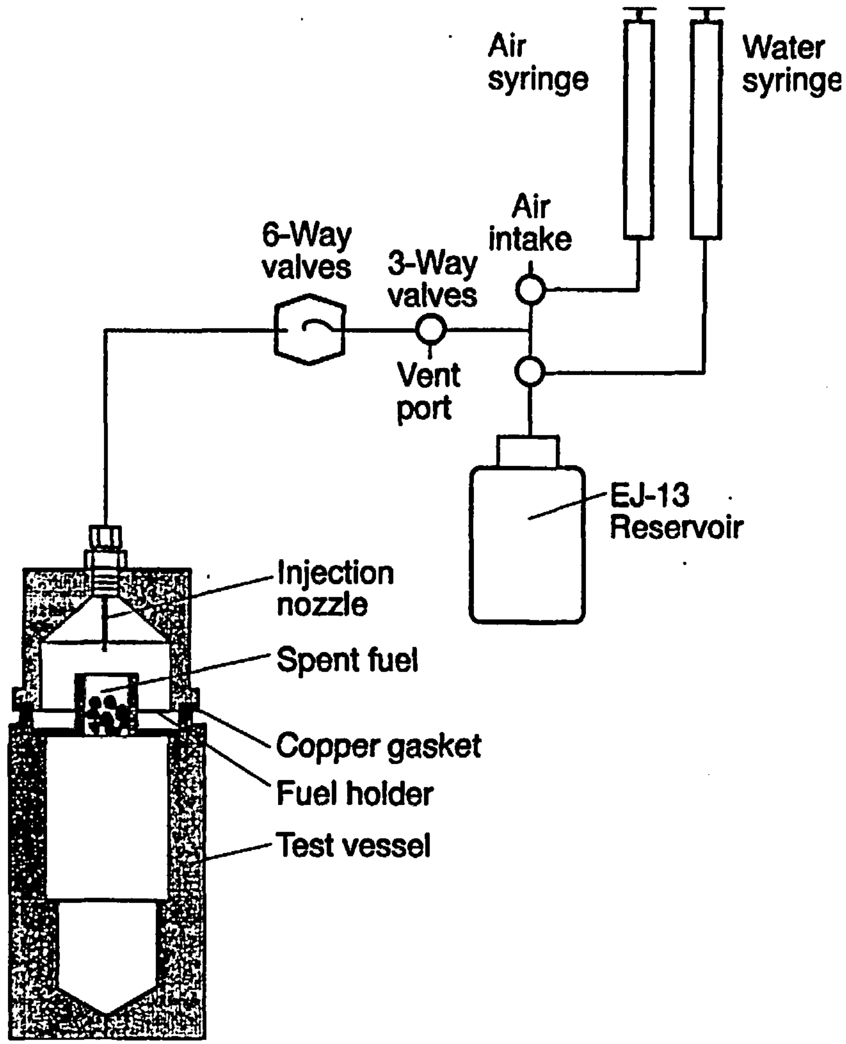
Overview

- Test Types:
  - Unsaturated Testing on Spent Fuel Pellet Fragments and UO_2
  - Unsaturated Testing on Segments of Clad Fuel Rods
- For Each Test Type:
  - Test Configuration and Operation
  - Objectives and Scope
  - Results

Spent Fuel and UO_2 Tests

- Unsaturated “Drip” Tests on Spent Fuel Pellet Fragments
- High Surface Area to Solution Volume Batch Tests
- Unirradiated UO_2 “Drip” Tests

Schematic - Spent Fuel Unsaturated Tests



High Solid-Surface-Area-to-Solution-Volume Batch Tests

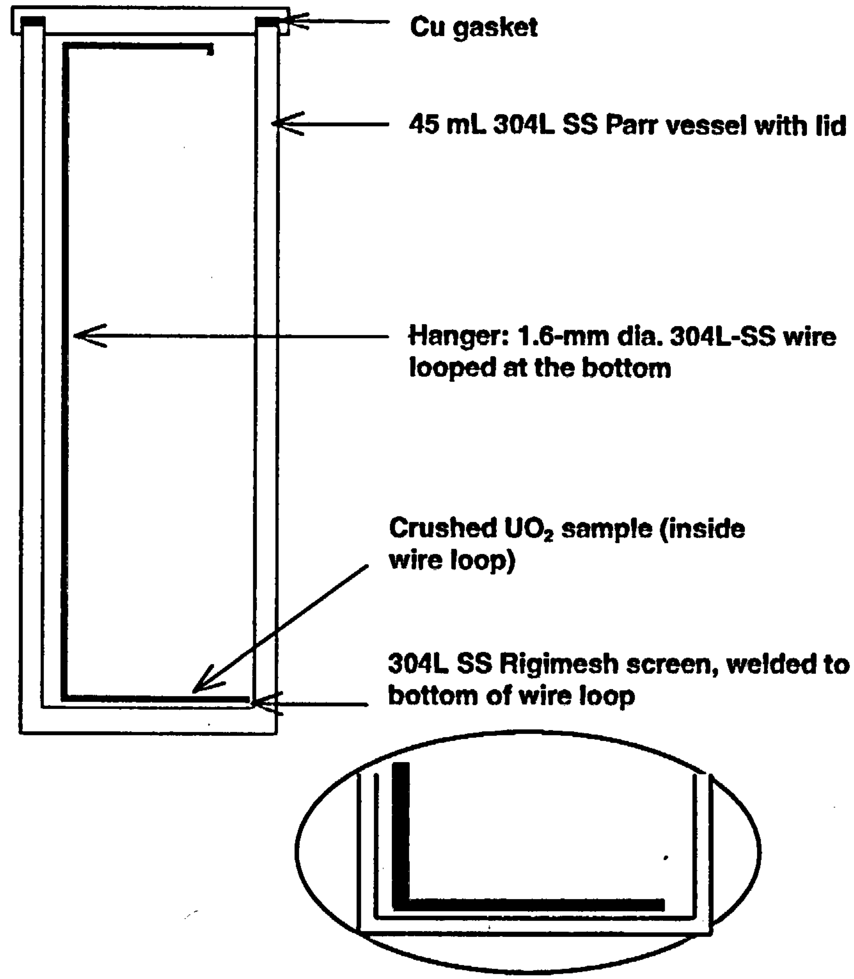
Batch Experiments

High S/V (~5000 m-1)

- Small Solution Volumes (0.5 mL)
- Crushed solids (0.2 g)

Analyze

- Solution
  - » changes in water film
- Solids
  - » reacted UO_2 or fuel
  - » alteration products



Objectives

- Examine the corrosion behavior of spent UO_2 fuels upon extended exposure to repository-relevant conditions
- The tests are designed to:
  - Determine the alteration modes
  - Determine the alteration products
  - Assess how the alteration modes and products influence radionuclide release

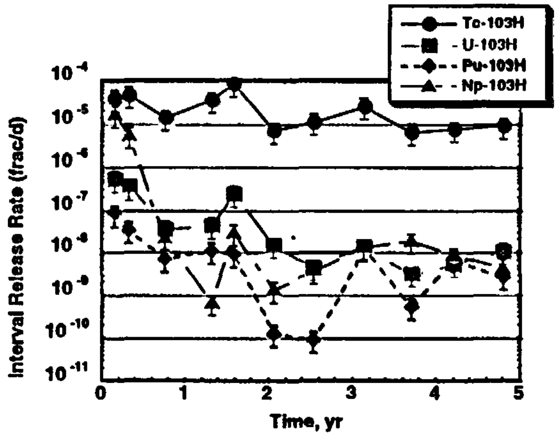
Scope and Status

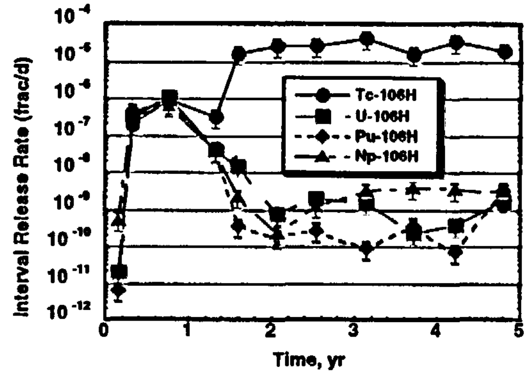
- Drip tests:
  - Three fuel types; ATM-103 and 106 (~6y); ATM-109(~1y)
  - Three groundwater contact modes (HDR, LDR, Humid Air)
- PDT tests:
  - ATM-103 fuels
- Drip tests on unirradiated UO_2 (~14y)

ATM-103 High-Drip-Rate Test

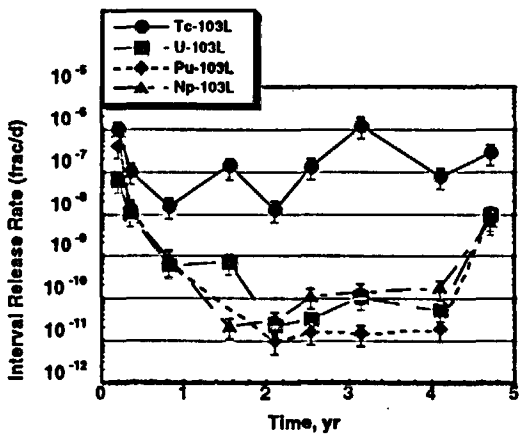
Interval Release Fractions - Tc, U, Np, Pu

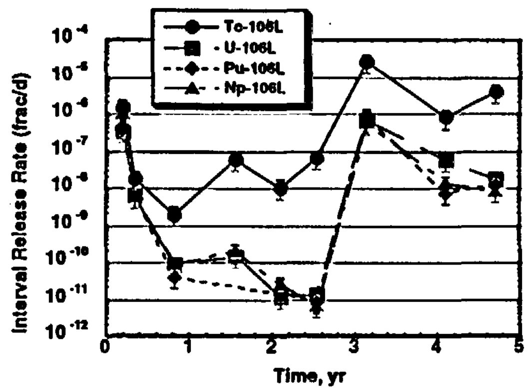
High-Drip-Rate





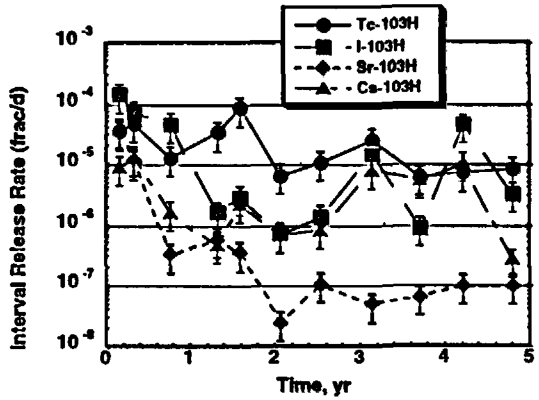
Low-Drip-Rate

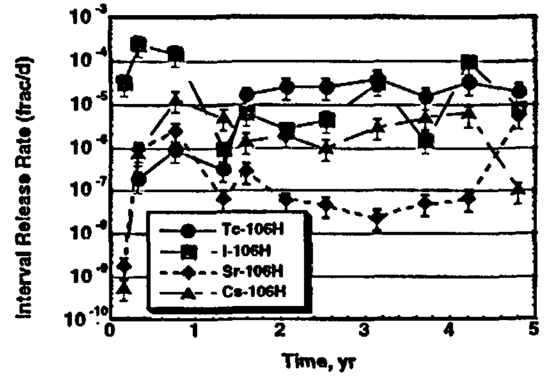




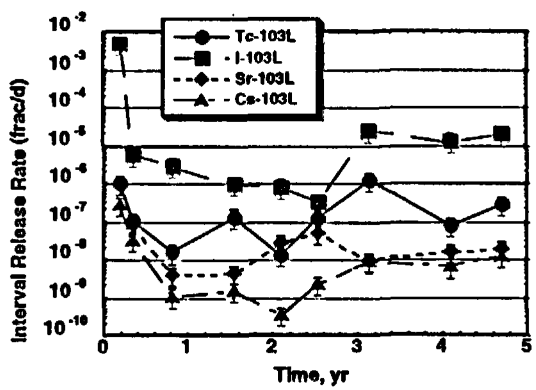
Interval Release Rates - Tc, I, Cs, Sr

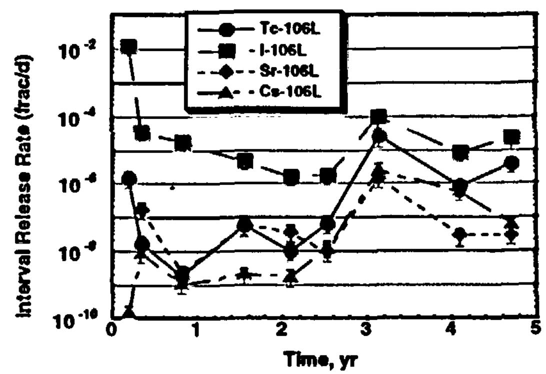
High-Drip-Rate



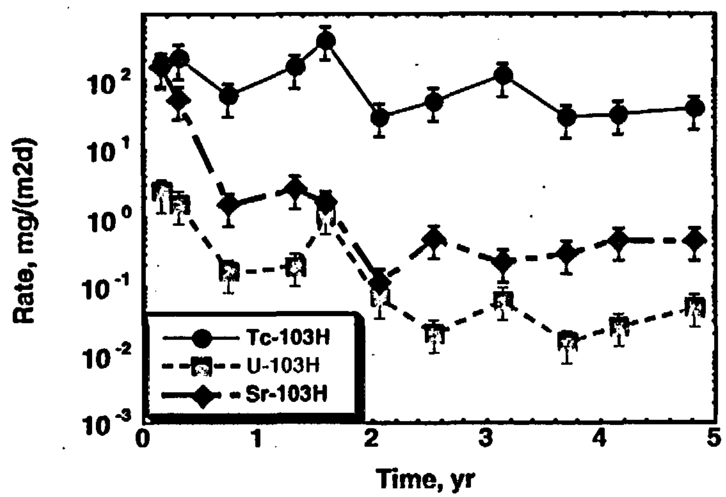


Low-Drip-Rate

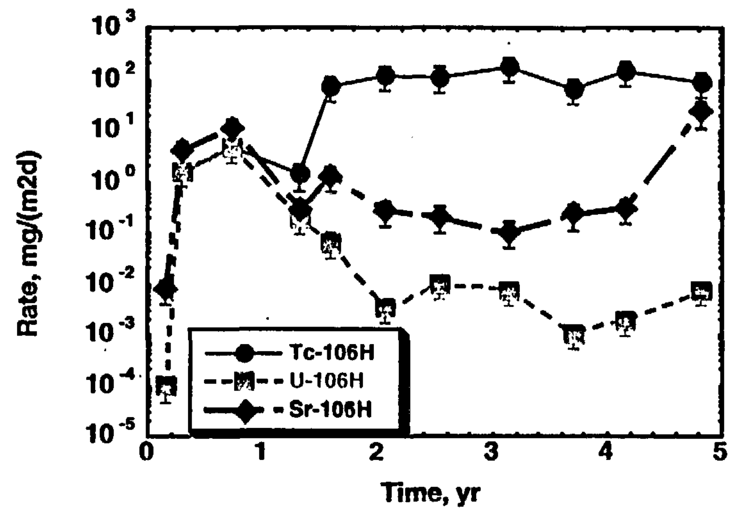




"Normalized" Rates of Release High-Drip-Rate Tests



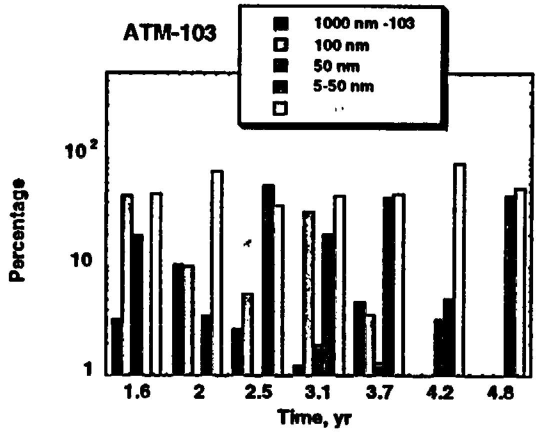
ATM-103

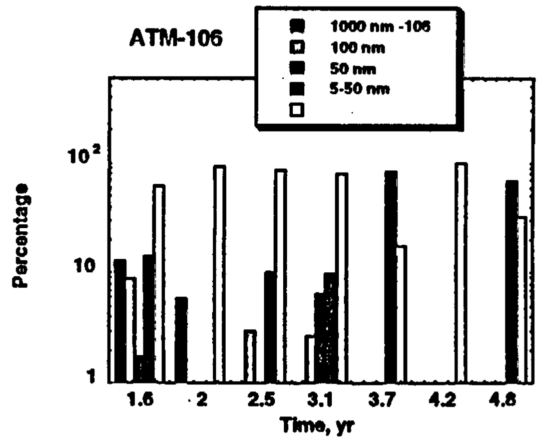


ATM-106

Pu Distribution in High-Drip Tests

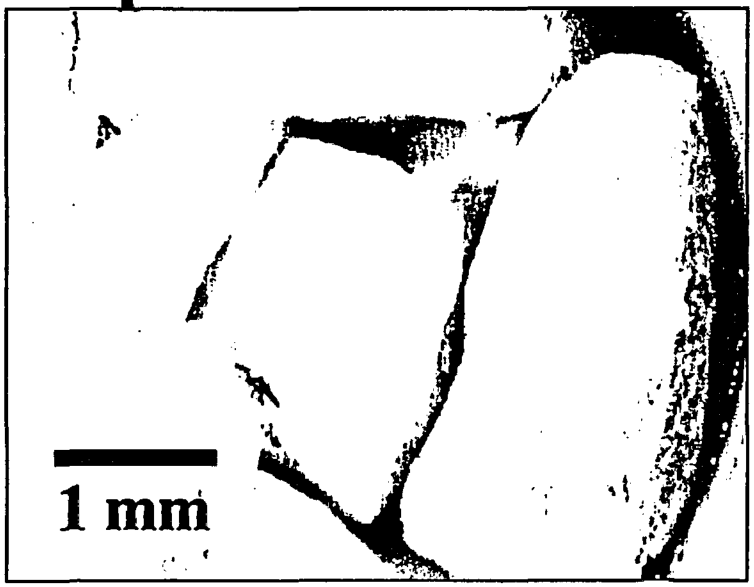
- The Pu in the leachate in the high-drip-rate tests was primarily associated with colloids or was sorbed on the stainless steel vessel's walls



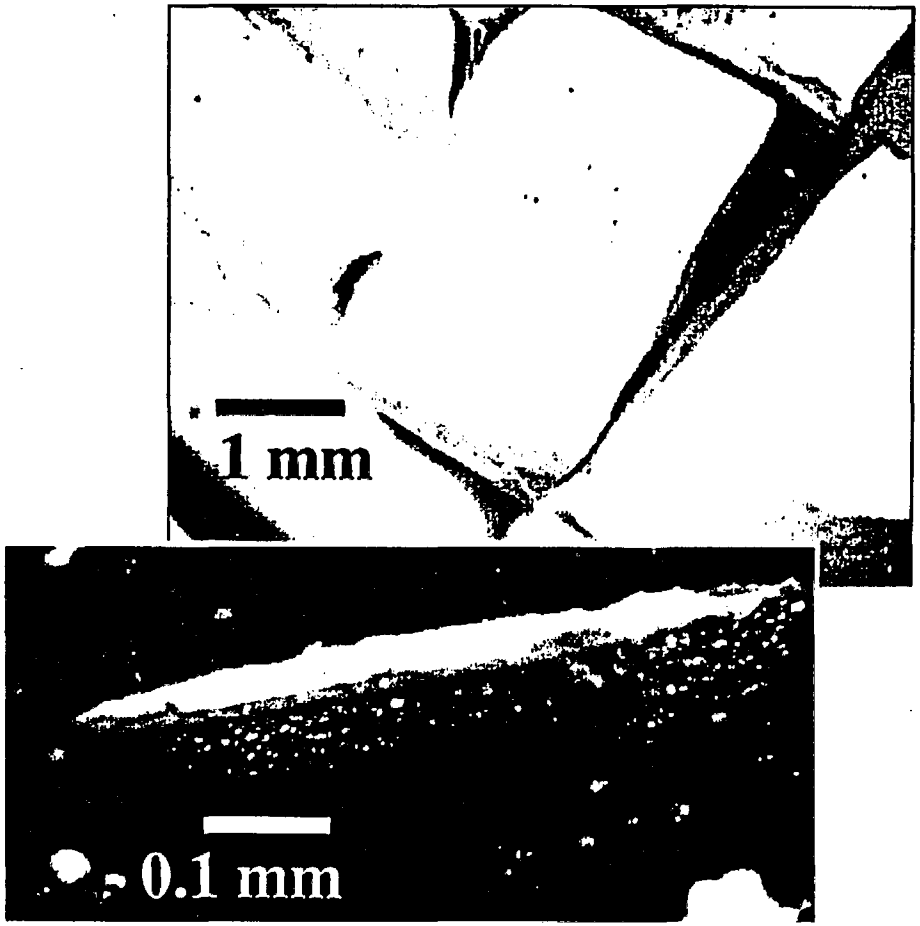


Corrosion Layers

Vapor

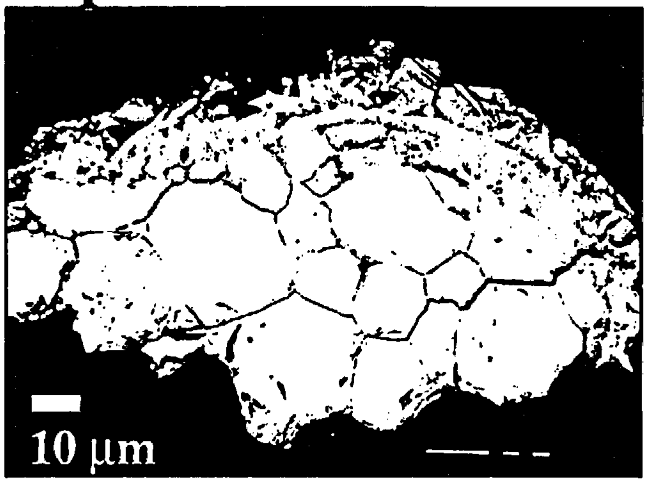


High Drip



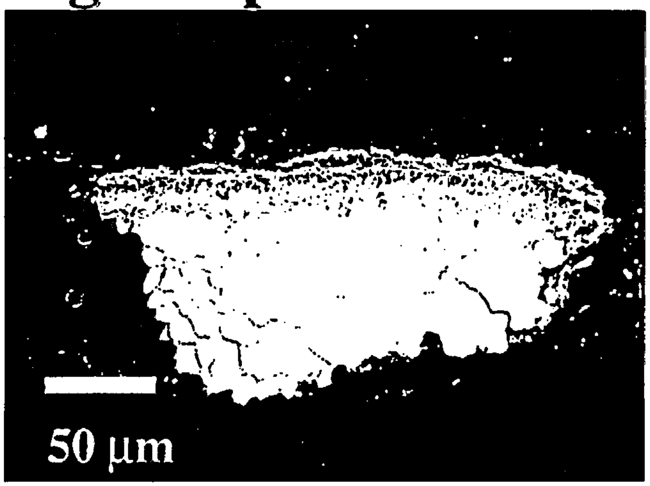
General Corrosion

Vapor

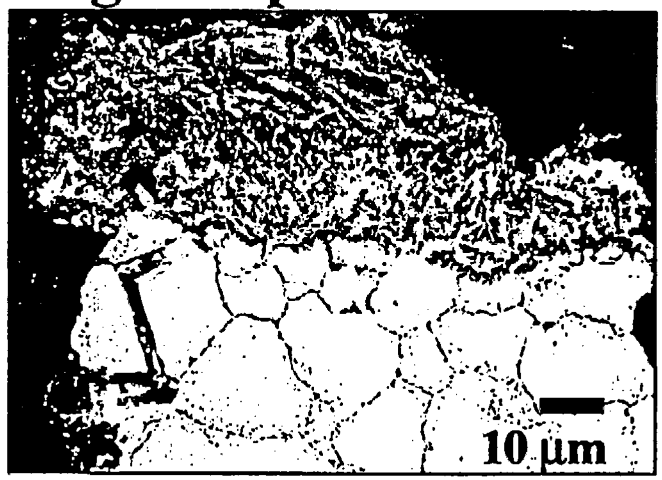


Low Drip

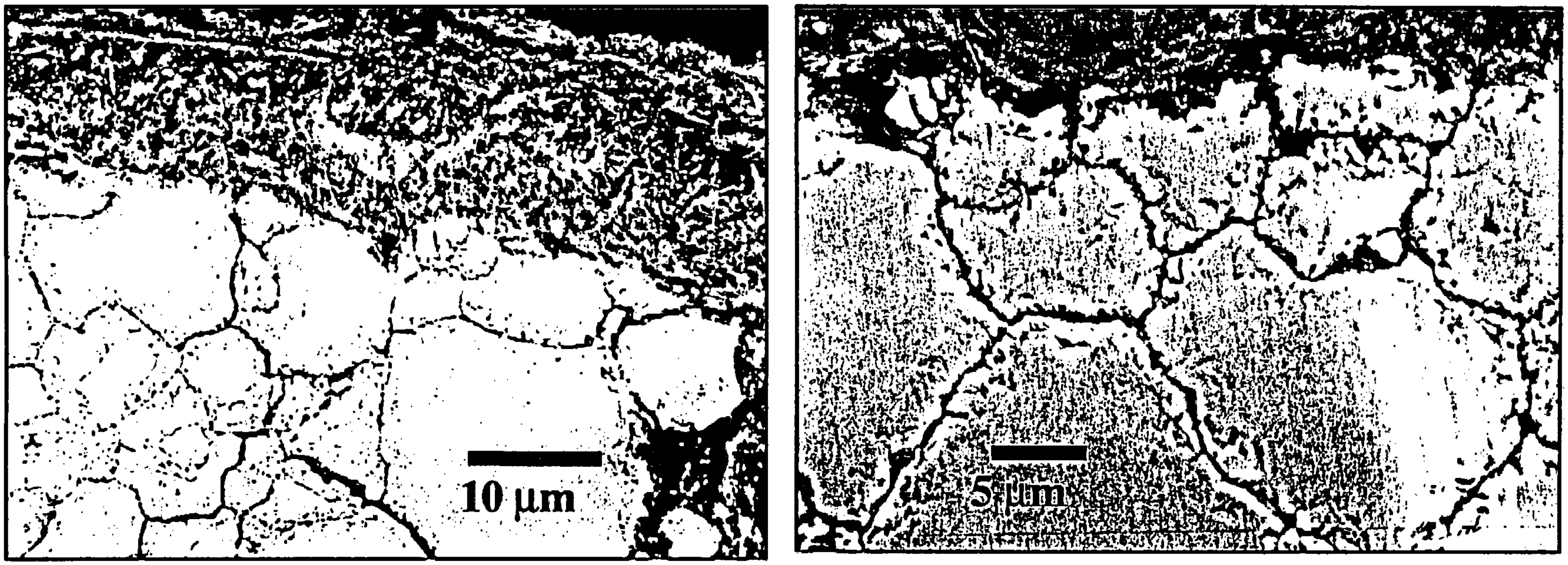
High Drip



High Drip



Grain Boundary Corrosion



ATM-103 High Drip-Rate

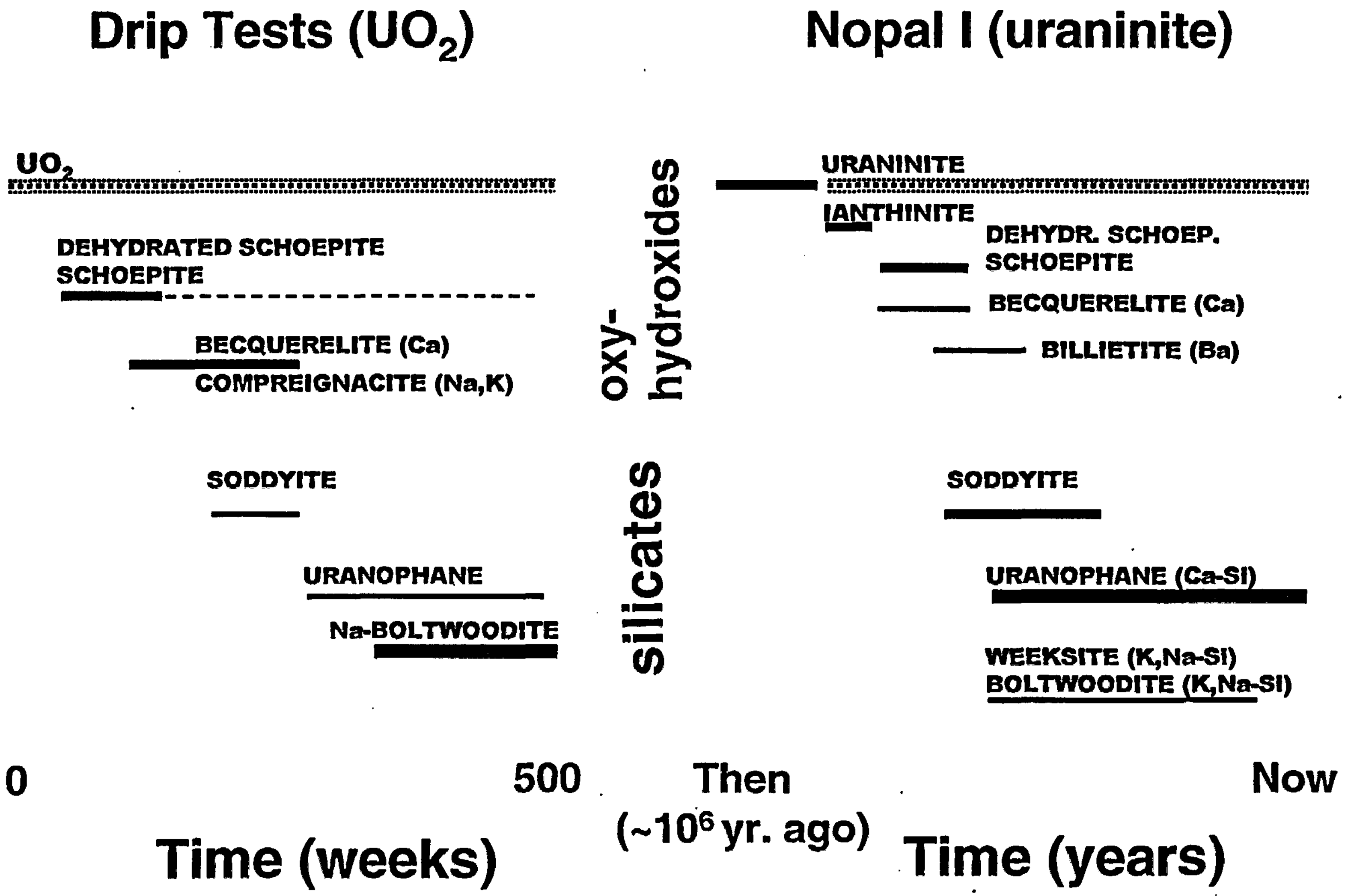
Experimental Paragenesis

Time →

	0 (vapor)	Low	High
Na,Ca uranyl silicates		(X)	X
Soddyite (uranyl silicate)		X	(X)
Uranyl oxy-hydroxides	X	X	(X)

Drip Rate →

Drip Tests Reproduce Natural Alteration

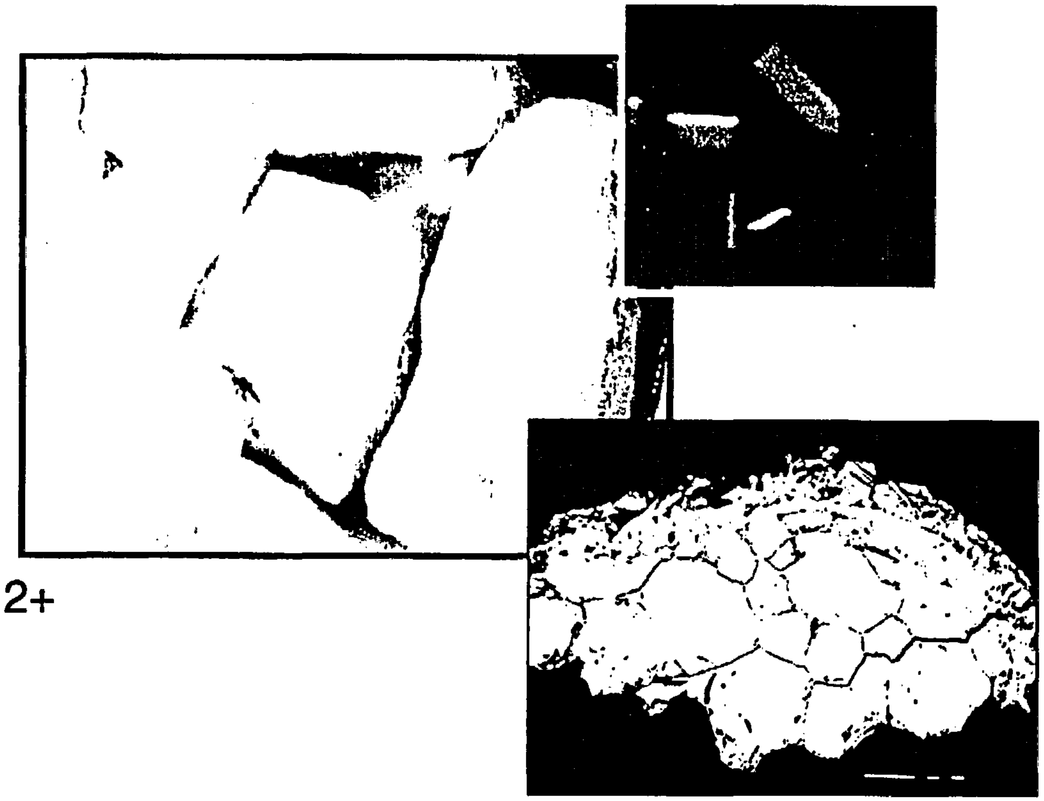


Np(V) in Dehydrated Schoepite

$UO_3 \cdot 0.9H_2O$

$(UO_2)O_{0.1}(OH)_{1.8}$

$(NpO_2)^+ + H^+ \leftrightarrow (UO_2)^{2+}$

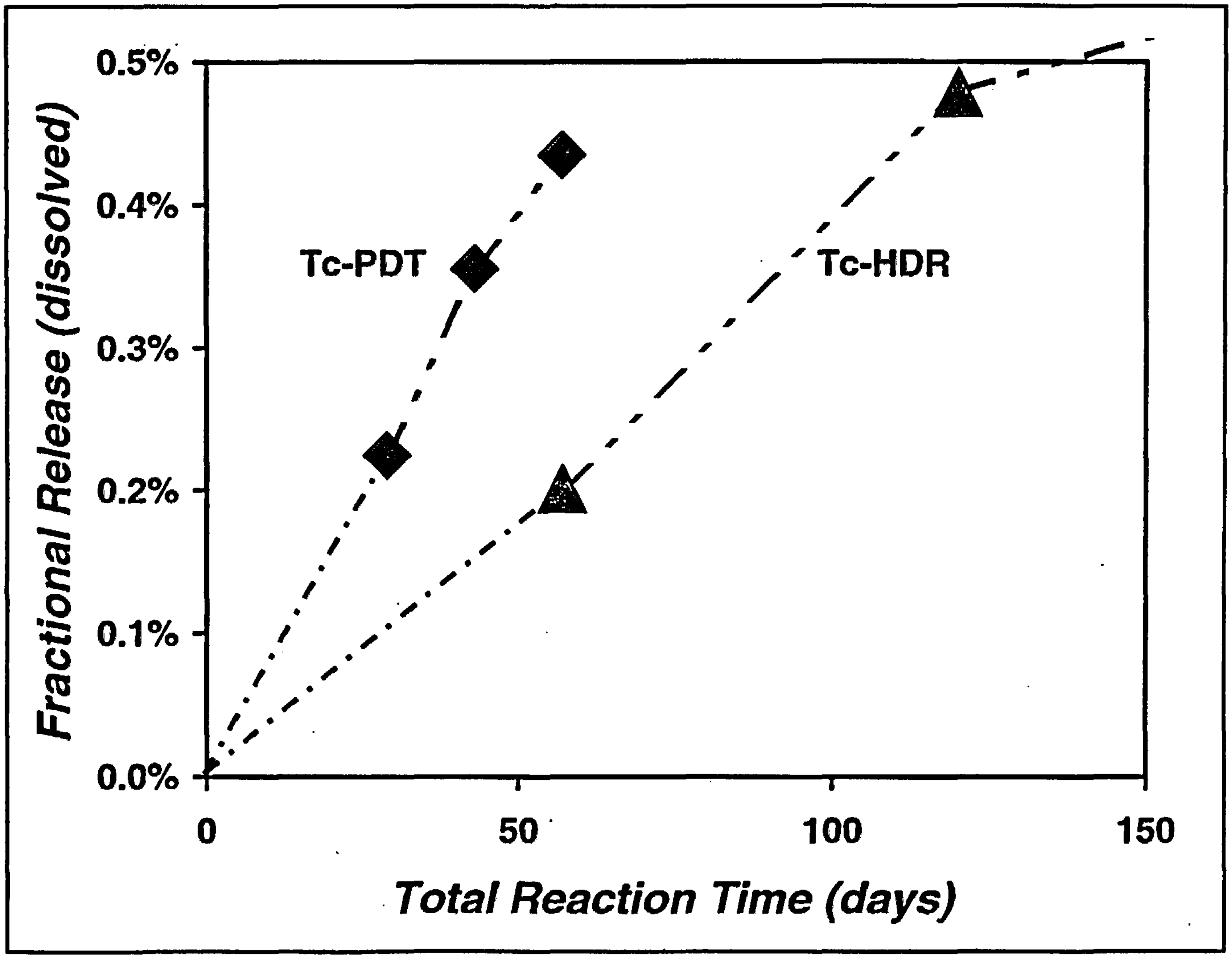


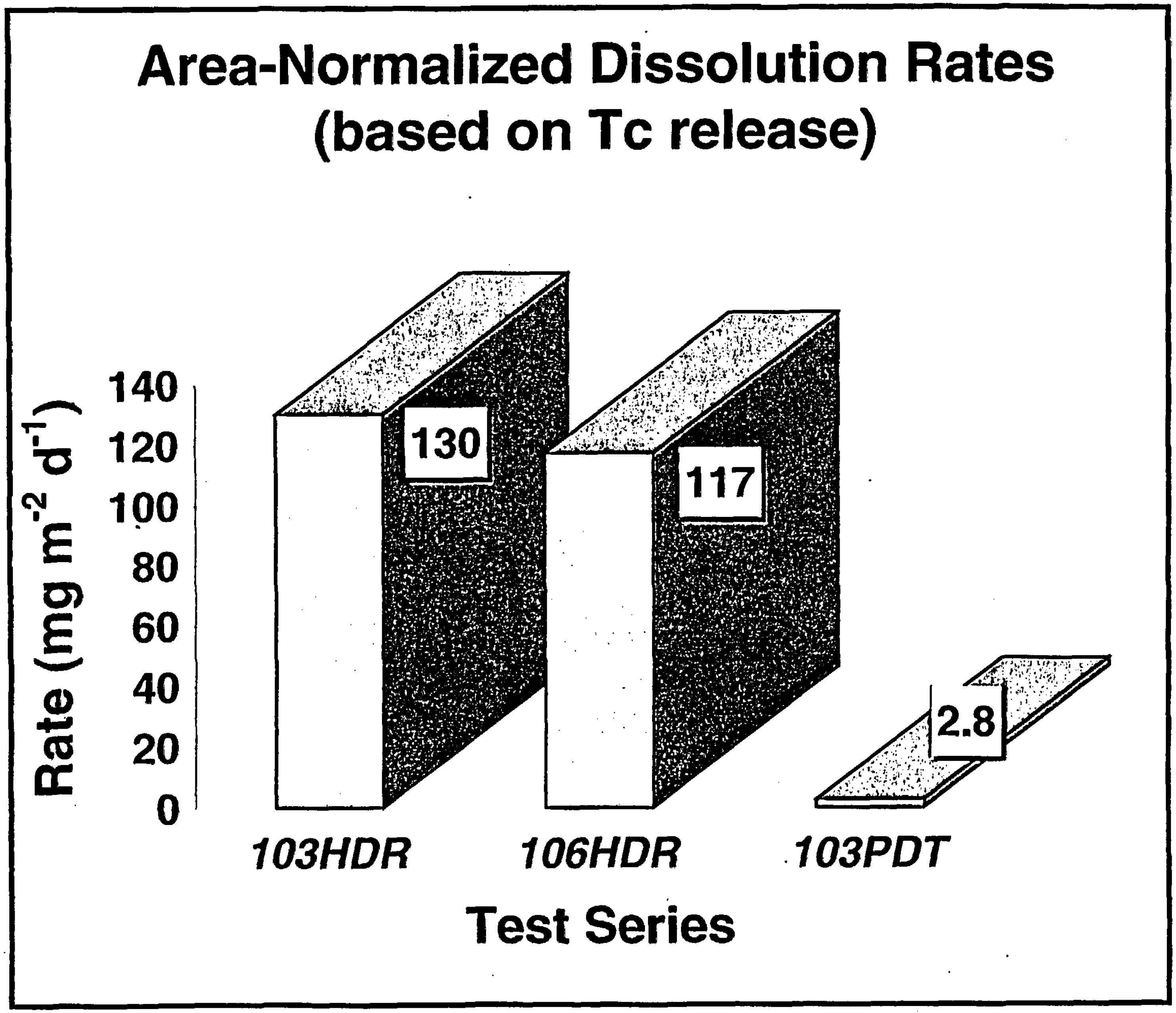
PDTs and Unsaturated Tests

a Comparison

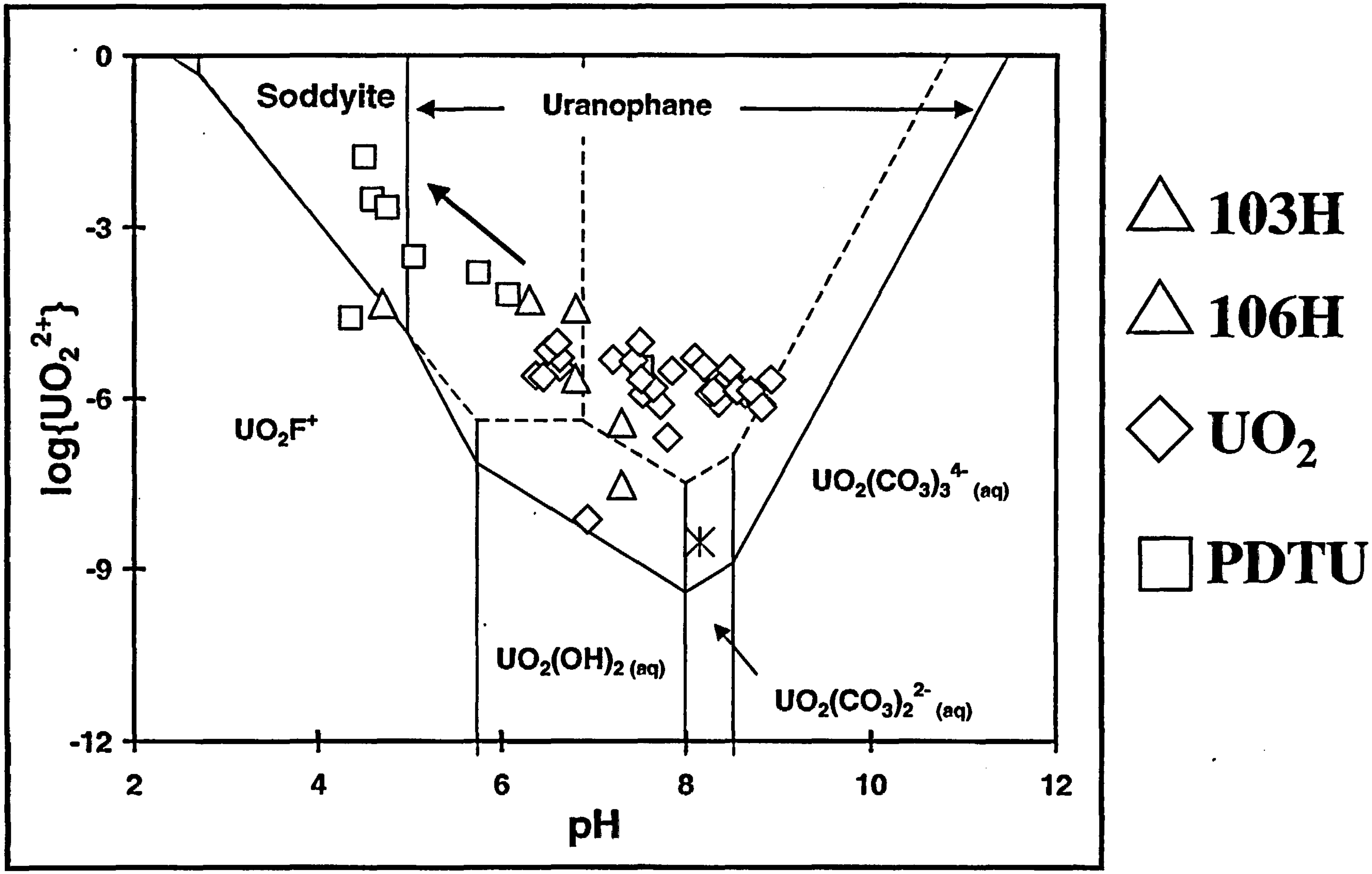
PDTs	Unsaturated Tests
Reactive surface area	Reactive surface area
» 2.5 to 9.5 x 10^{-3} m^2	» 1.7 x 10^{-3} m^2
Alteration phases	Alteration phases
» Uranyl oxy-hydroxide	» Uranyl oxy-hydroxides
» Uranyl silicates	» Uranyl silicates
Test Design	Test Design
» Small-scale batch tests	» Flow-type tests
» Simple vessel design	» Complex vessel design & Drip apparatus

ATM-103 Fractional Tc Release PDT and HDR




Area-Normalized Dissolution Rates
(based on Tc release)
Rate (mg m-2 d-1)
140
120
100
80
60
40
20
0
130
117
2.8
103HDR
106HDR
103PDT
Test Series

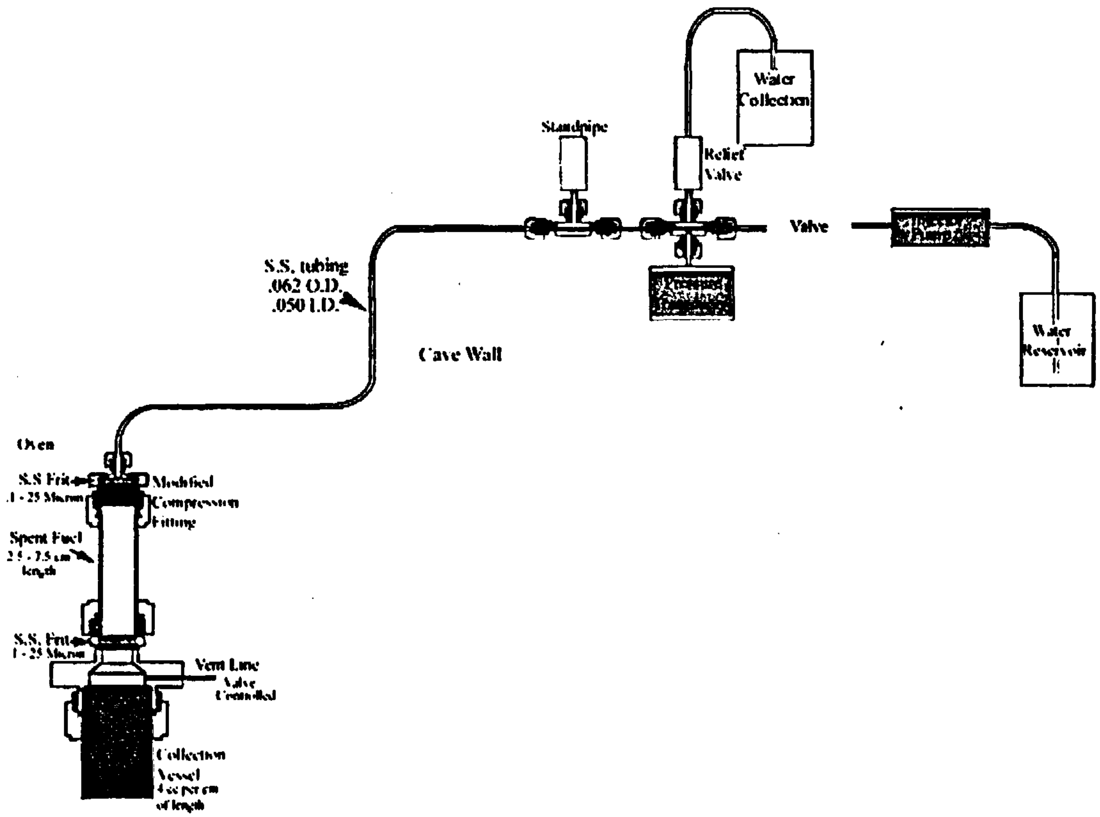
Solution Compositions for UDTs (UO_2 and SNF)



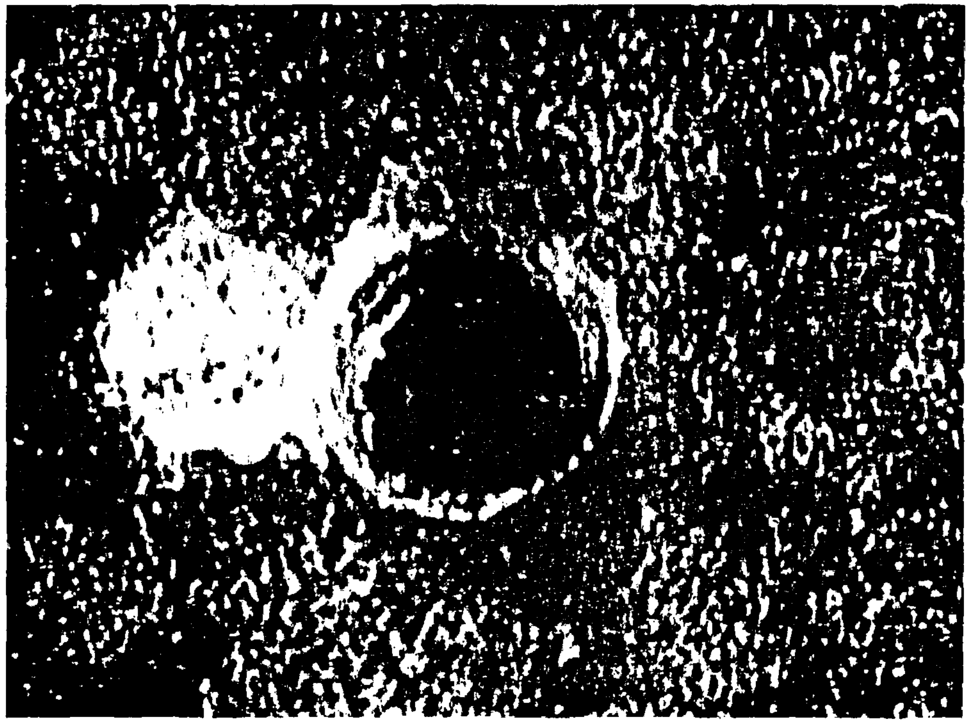
Clad Fuel Tests

- Four Vapor Tests (ATM103; 3.5 inch segments; 175°C and 100% RH)
  - Capped at each end with Ti Swagelok fittings
  - 1/16-inch defect in cladding
- Five Drip Tests (2,3,4 inch ATM103, 2 inch ATM106, and 3 inch ATM109)
  - 0.75 mL of EJ13 injected twice a week

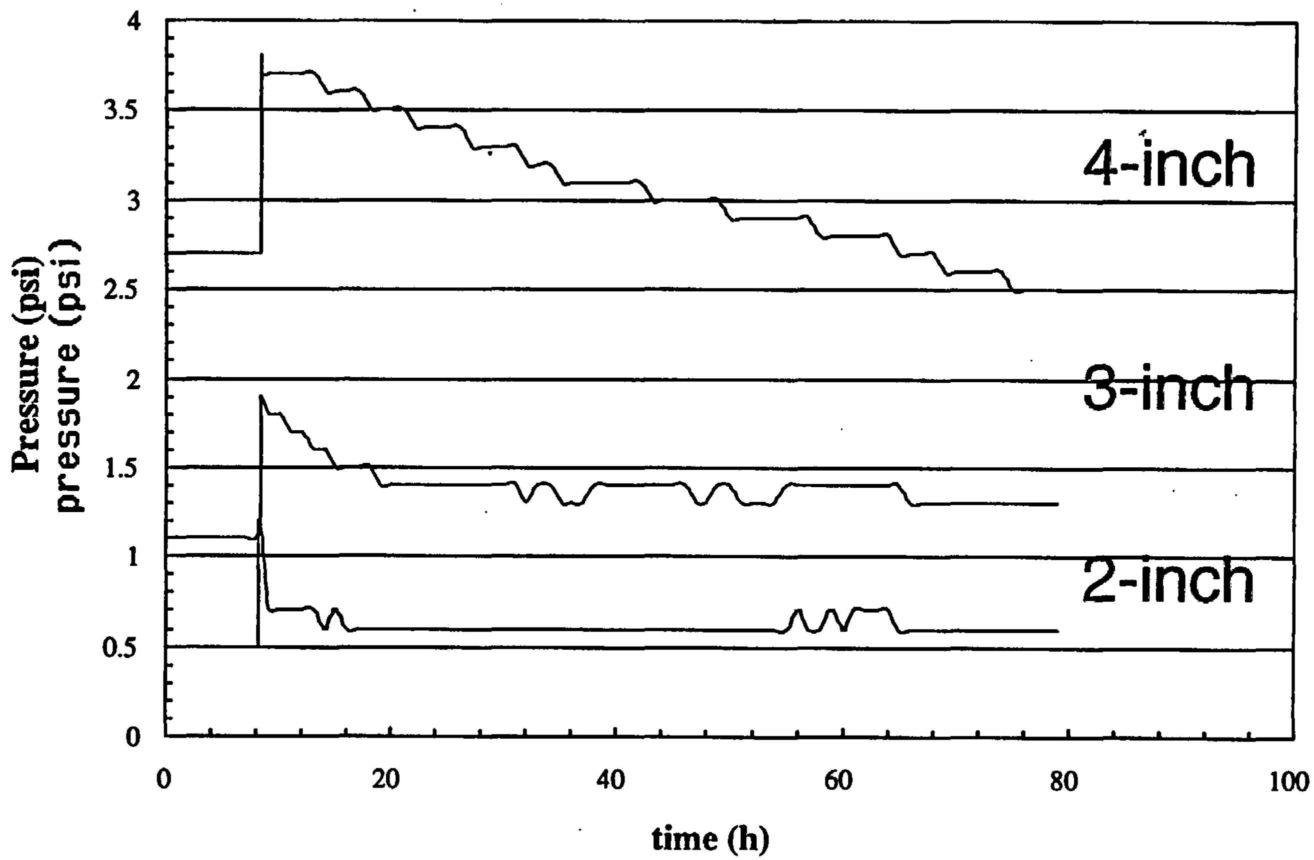
Clad Fuel Drip Tests



Clad Fuel Vapor Integrity Tests: 152-d Reaction



Pressure Transducer Output: ATM103



Summary

- General and grain boundary corrosion
- Incongruent release of radioelements
- U alteration phases consistent with observations of uraninite alteration
- "Normalized" corrosion rates (based on Tc) are higher in drip tests than in PDTs
- Solution U concentrations indicate solution saturation
- Clad fuel vapor and drip tests started