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Office of River Protection Glass Science Program

Briefing for the Independent Peer Review Panel of the Analysis of Supplemental Treatment Approaches of Low-Activity Waste at the Hanford Nuclear Reservation by the Federally Funded Research and Development Center

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United States Department of Energy

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RICHLAND OPERATIONS OFFICE
United States Department of Energy

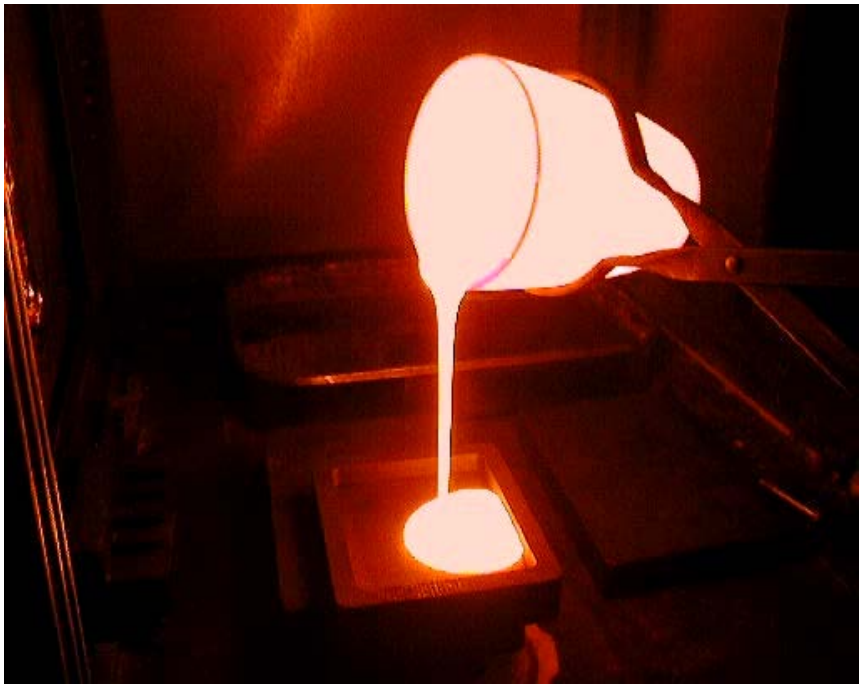
Presentation Outline

- BRIEF overview of the current work on glass development for treatment of high-level and low-activity waste at Hanford
- National and international context for developing high-level and low-activity waste forms
- Office of River Protection (ORP) efforts related to glass development and future directions
- Research to support sound engineering decisions with the greatest potential for a positive effect on the cost, duration and effectiveness of the Environmental Management Vitrification program

Key Messages

- Incorporation of advanced glass formulations allows for greater flexibility of the economics of the ENTIRE treatment mission
- Advanced low-activity waste (LAW) glass formulations allow the additional flexibility to reconsider feed vectors to the Waste Treatment and Immobilization Plant (WTP)
- Performance enhancements through improved glass formulations are essentially transparent to the engineered facility
- The ORP Glass Program is based on a foundation of independent peer-reviewed work. This affords a high level of confidence of success in engineering execution.

Reducing the Cost and Schedule for Mission Completion



- Improve LAW and high-level waste (HLW) glass waste loadings
- Increase HLW glass production rate
- Optimize HLW and LAW melter performance
- Enhance HLW and LAW glass property-composition models

What's in the Tanks

Saltcake
23M gallons

Mostly water-soluble salts; small amount of interstitial liquid

Supernate
21M gallons

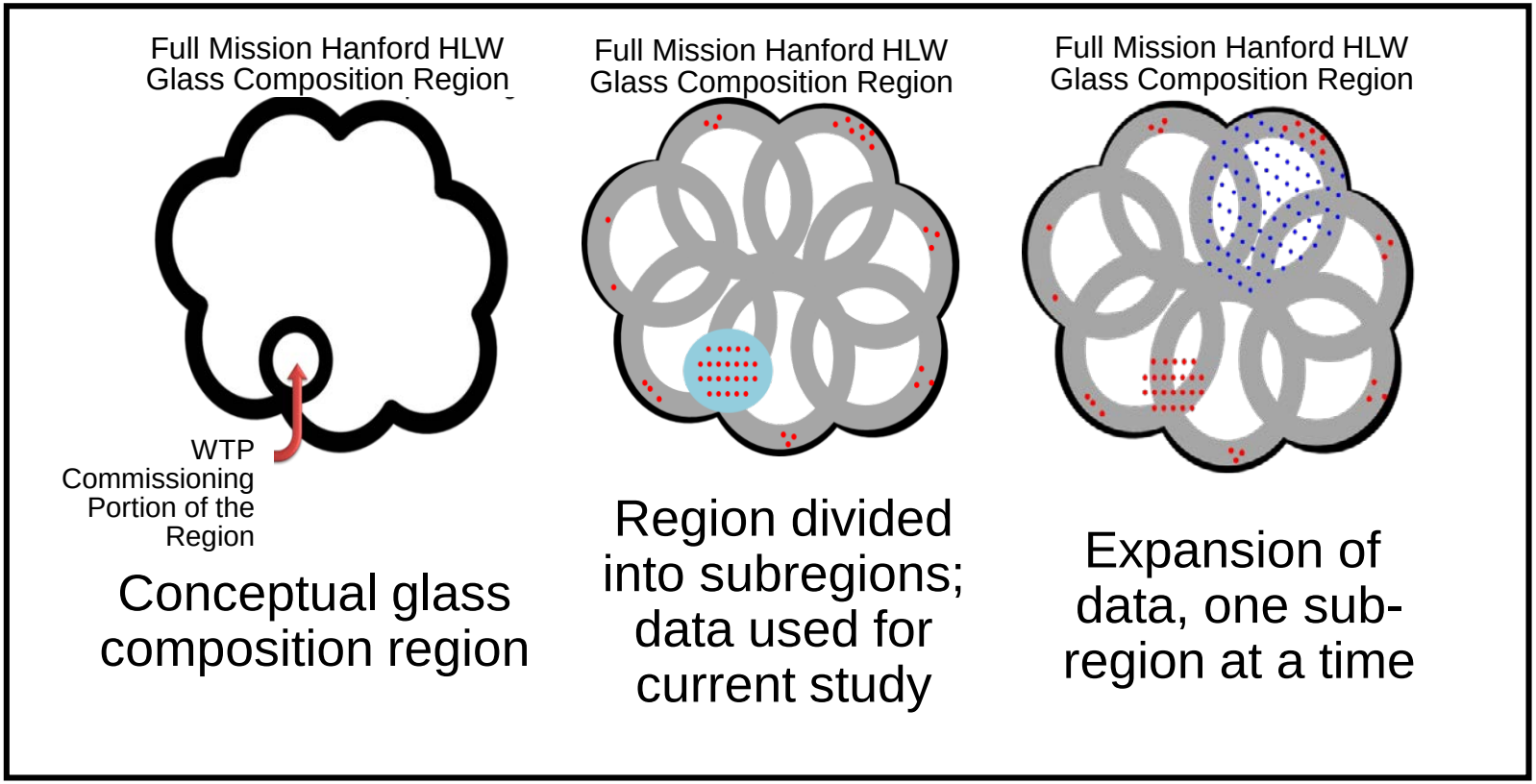
Any non-interstitial liquid in the tanks – similar to saltcake in composition

Sludge
12M gallons

Water-insoluble metal oxides, significant amount of interstitial liquid – texture similar to peanut butter

What Still Needs to Be Done

Only a small fraction of the ORP HLW glasses fall within the validity range of the existing WTP baseline models.



Formulating Glass

$$g_i = Ww_i + (1-W)a_i$$

$$P = \hat{P}_T(g_1, g_2, \ldots, gn)$$

For a given waste composition (wi),
determine mineral addition (ai),
to obtain glass composition (gi),
with optimized properties (P),
and maximized waste loading (W)
The selection of properties to be optimized depends on melter technology and glass acceptability criteria

WTP Baseline vs. Balance of Mission

WTP Scope

- Focused on WTP contract requirements
- WTP contract requirements intended to provide for a reasonably achievable baseline
- Waste loading and melt rate requirements are reasonably conservative
- Focused on early tanks (AZ-101, AZ-102, C-106/AY-102 – high iron, and C-104/AY-101 – high zirconium and thorium) for HLW

ORP Balance of Mission Testing

- Enhancements beyond the WTP baseline
- Advanced glass formulations
  - Increase waste loading to reduce the amount of LAW and HLW glass produced
  - Maximize processing rate
- Address balance of mission feeds (high Al, Bi/P, S, Cr, etc.)
- Enhance reliability of project completion and life cycle cost estimates

Performance enhancements through improved glass formulations are essentially transparent to the engineered facility

ORP Glass Formulations

- In fiscal year 2007, ORP initiated a testing program to develop and characterize HLW and LAW glasses with higher waste loadings and, where possible, higher throughput, to meet the processing and product quality requirements
- This effort spans the investigation of the melt dynamics and cold cap properties to vitrification processes at the conditions close to those that exist in continuously fed waste glass melters

	BNI/WTP Baseline Models	2008 Tank Utilization Assessment (TUA)* Baseline
HLW Canisters	18,400	14,838
LAW Containers	145,000	91,400
Total Canisters and Containers	163,000	106,238

*The “2008 models” were advanced in anticipation of our work

Five containers a day at 70% availability projects a 114-year mission for LAW

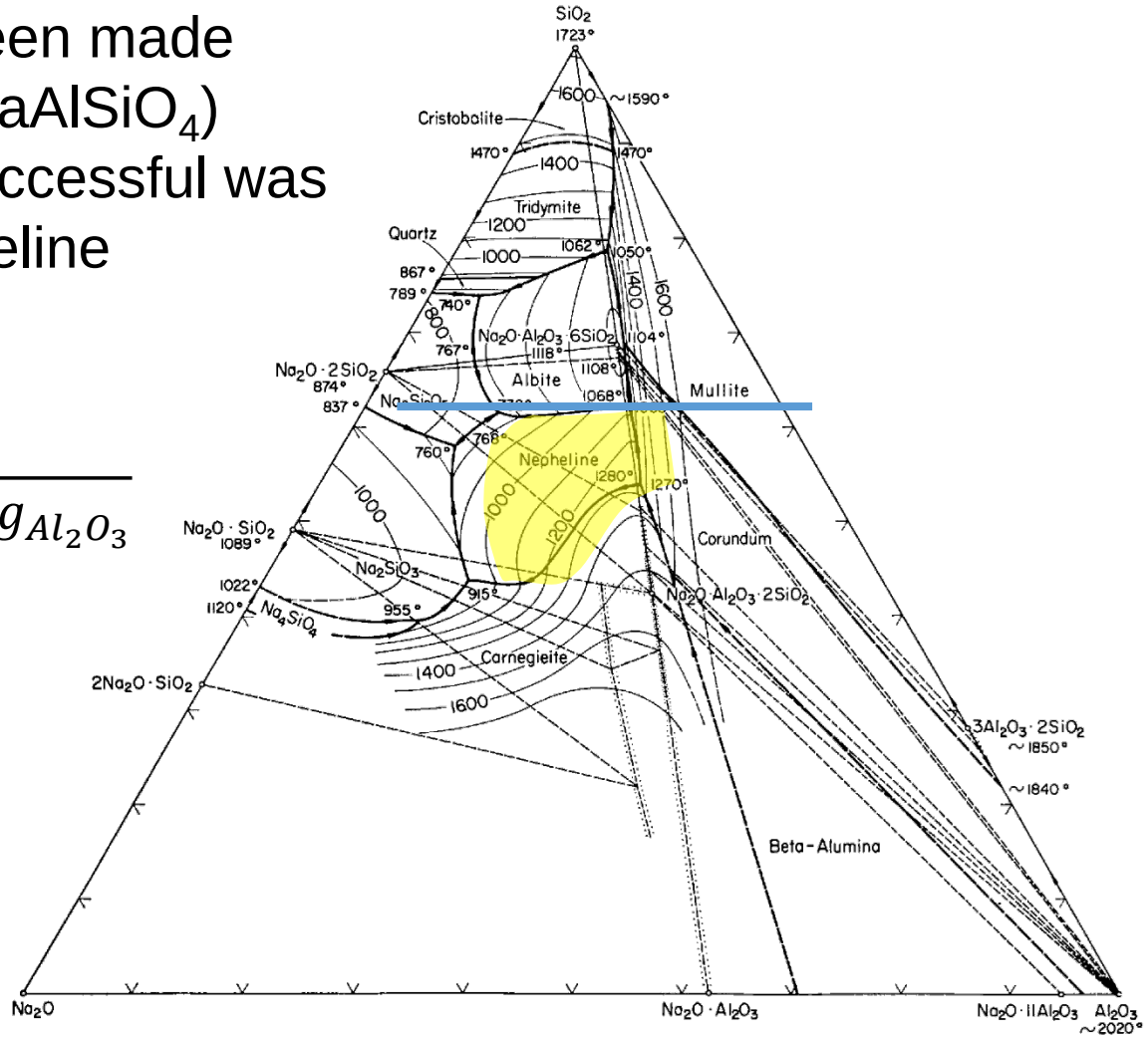
Our Partners

Pacific Northwest National Laboratory	Catholic University/Vitreous State Laboratory
Savannah River National Laboratory	Corning Laboratory
Idaho National Laboratory	Commissariat d'Energie Atomique
Washington State University	University of South Carolina
Rutgers University	Akita University
University of Sheffield	Tokyo Institute of Technology
University of Chemistry & Technology	Luleå University of Technology
Vanderbilt University	National Institute of Standards & Technology (NIST)
Sheffield Hallam University	Smithsonian Conservation Laboratory
University of Utah	Pohang University of Science and Technology

This is All About Aluminum Salts

Many attempts have been made to predict Nepheline ($NaAlSiO_4$) formation. The most successful was the Li et al. 1997 Nepheline discriminator:

$$ND = \frac{g_{SiO_2}}{g_{SiO_2} + g_{Na_2O} + g_{Al_2O_3}}$$



HLW Results that Affect LAW

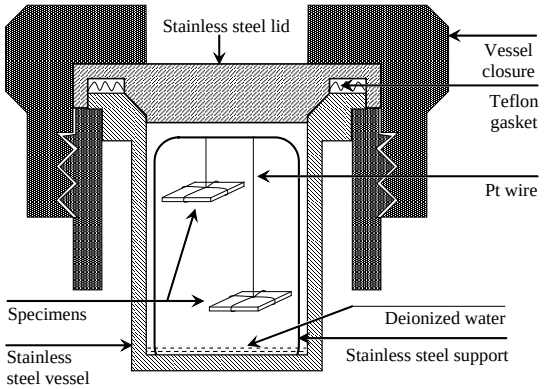
- Demonstrated the feasibility of increases in waste loading from 25 wt% to 33-55 wt% (based on oxide loading) in the glass, depending on the waste stream
- This work has resulted in immobilized HLW glasses with waste loadings at 50 wt% (with >30 wt% Al_2O_3) vs. 25 wt% (with 11 wt% Al_2O_3) in WTP Contract (TS-1.1)
- Increased tolerance for sulfur in challenging waste streams high in Al, or Al plus Na or Bi or Cr or Fe

What are We Doing?

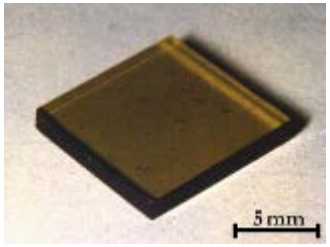
- Developing models for plant operation and the algorithm for operations
- Developing the process scheme and data for potential direct-feed HLW application
- Need to improve LAW loading only slightly more to enable 30-year mission with single LAW facility; this can be accomplished by removing Vapor Hydration Tests (VHT), breaking recycle, and/or incremental improvements in models
- Need to complete cold cap / melting rate model vs. feed composition
- Need to complete and deliver enhanced waste glass models for operations

What Still Needs to Be Done

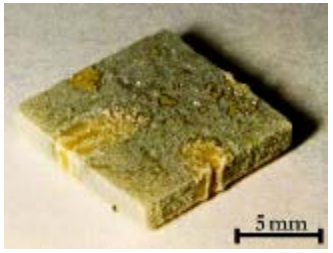
*2.2.2.17.3 "The glass corrosion rate shall be measured using at least a seven (7)-day vapor hydration test run at **200 °C**."*
"The measured glass alteration rate shall be less than 50 grams/(m^2 day)."

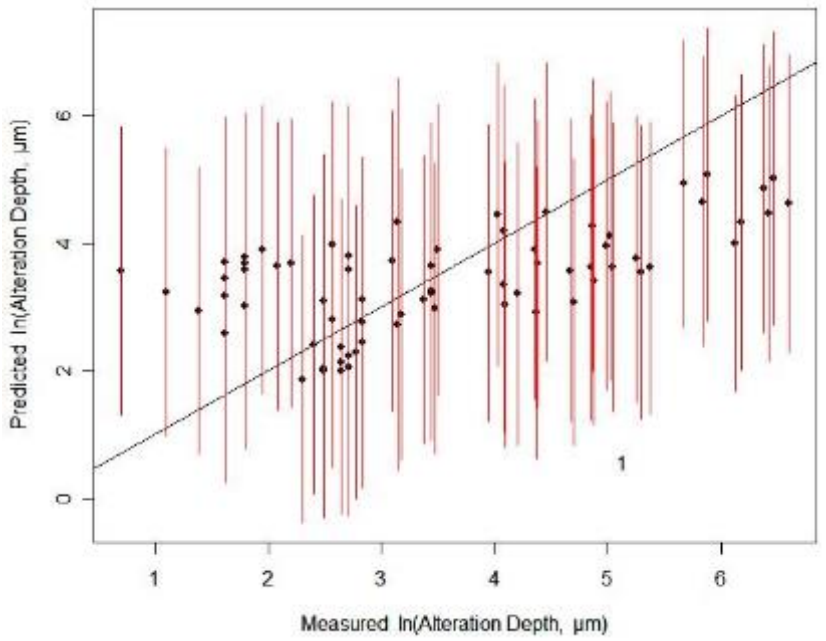


0 days



15 days





The Vapor Hydration Test (VHT)

- ✘ High variability between labs
- ✘ High variability between operators
- ✘ Inconsistent with assessment of glass durability under the anticipated disposal conditions
- ✘ Large uncertainties in dissolution rate

Project Objectives

The GLAD Project
Aim: To design a new test for LAW glass that is more representative of low-temperature corrosion

Develop a low-temperature glass corrosion test

Confirm ease and reproducibility between three laboratories

Exchange the controversial VHT test for the new test

The Hillfort Project
Aim: To validate the chosen low-temperature test against natural analogues from 2,000-year-old Swedish Hillforts

Take glass samples from Swedish Hillfort

Study corrosion and corrosion environment

Make glass of identical composition

Apply test to Hillfort glasses and validate

Top 5+

Top 5 most important new technologies implemented in the past two years:

- Oxidative Leaching
- Caustic Leaching
- Supplemental LAW
- Design and Operability Review of Heating, Ventilation and Air Conditioning (HVAC)
- New Glass Models
- Feed Vector Flexibility
- Tc Retention

Results and Effects for LAW

- Demonstrated increases in glass production rates and significant increases in sulfate incorporation at the nominal melter operating temperature of 1,150 °C
- Demonstrated further enhancement of glass formulations for all of the LAW waste envelopes (as defined in contract), reducing the amount of glass to be produced by the WTP
- This approach was subsequently applied to an even wider range of LAW wastes types (i.e., LAW feed), including those with high potassium concentration
- The feasibility of formulating higher waste loading glasses using SnO_2 and V_2O_5 in place of Fe_2O_3 and MgO as glass-former additives was also evaluated
- The next phase of testing determined the applicability of these improvements over the expected range of sodium and sulfur concentrations for Hanford LAW
- Potential to realize nearly the entire soda inventory in the WTP LAW Facility and within an acceptable mission duration

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ORP Mission Duration with ORP 2013 Glass Models

	BNI/WTP Baseline Models	2008 TUA* Baseline	2013 TUA Baseline	2013 TUA with caustic and oxidative leaching eliminated
HLW Canisters	18,400	14,838	8,223	13,534
LAW Containers	145,000	91,400	79,465	65,151
Total Canisters and Containers	163,000	106,238	87,688	78,685

*24590-WTP-RPT-PE-13-003, Rev 0, 2013 Tank Utilization Assessment (TUA) Part 1: Potential Impact of Advanced Glass Models on the WTP, 3 December 2013

Five containers a day at 70% availability projects a 51-year mission for LAW

Communications

Questions?


The Hanford Reach
White Bluffs Overlooking the Columbia River