Tank Waste and Melter Feed Simulants

Glenn Diener – Energy*Solutions*

I.S. Muller, W. K.Kot, and I.L. Pegg – VSL

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Overview

- Over 350 bench-scale and 50 pilot-scale waste and melter feed simulants tested at VSL (both HLW & LAW)
- To ensure validity and suitability of simulants used for vitrification tests:
  - Compared to existing waste characterization data
  - Adapted to suit each test for which they were used
- To provide a rational basis for selection of glass former additives:
  - Evaluated the impacts of glass former additives on feed properties and stability
  - Evaluated cost and availability of materials
- To provide a rational basis for selection of operating ranges for waste concentration and melter feed solids content

Test Objectives

- Support melter and feed mixing tests
- Provide specifications of glass former additives for the target waste streams
- Obtain waste simulant and melter feed characterization data
- Determine effects of process variations (i.e., pH, solids content, temperature …) on feed stability
- Determine operating ranges for waste concentration and melter feed solids content and correlate to rheological properties

Simulant Parameters

Controlled Variables

- Waste chemical composition (envelope definition)
- Chemical selected for waste simulant (e.g., $Al(NO_3)_3 \cdot 9H_2O$ vs. $Al(OH)_3$)
- Minerals vs. reagents or technical grade chemicals (e.g., kyanite vs. Al_2O_3) as glass former additives
- Chemical selected for glass former additives (e.g., Li_2CO_3 vs. LiOH)
- Water Content
- Temperature (25 to 40 °C)
- Aging (feed stability with time) from 1 to 30 days
- Glass former additive particle sizes
- Order of addition
- Others: waste organic content, use of reductant (sugar), use of simulant modifiers (e.g., PAA, xanthan gum), use of surfactants

Simulant Parameters

Response Variables

- Density
- pH
- Total solids content (total dissolved solids & total suspended solids)
- Settling rate
- Particle size distribution
- Rheological properties (shear viscosity vs. shear rate & yield stress)
- Glass yield
- Time dependence (i.e., feed stability)

Simulant Design Strategy

- Chemical compositions based on inventory (TFCOUP) data and actual waste characterization
- Physical properties of melter feeds simulated to the extent possible but generally secondary to chemical composition
- Selection of starting materials based on actual waste data (hydroxides and oxides), availability, and costs
- For HLW - selection of non-radioactive surrogates to replace radioactive components determined by test objectives (e.g., U, Th replaced by Ce, Zr, Hf, Nd, etc., or simply omitted based on properties measured of radioactive glass and surrogate glasses)

LAW Simulants

- LAW Waste Simulant:
  - Na: sodium nitrate, sodium nitrite, sodium hydroxide, and sodium carbonate
  - Al: $Al(NO_3)_3 \cdot 9H_2O$ or a blend of $Al(NO_3)_3 \cdot 9H_2O$ and $Al(OH)_3$
  - K: hydroxide or carbonate
- LAW Glass Former Additives:
  - Kyanite, H_3BO_3, wollanstonite,…

HLW Simulants

- HLW Waste Simulant:
  - Mixed chemicals
    - Precipitated hydroxide method screened out as unnecessary and impractical from a cost perspective
  - Major components: $Fe(OH)_3$ slurry, other oxides and hydroxides
- HLW Glass Former Additives:
  - Chemicals only (no minerals) provided better control of material purity
  - Major components: Technical grade borax, soda ash, silica

Simulant Scale Up

- Made in-house and by industrial vendors (NOAH Technologies, Optima Chemicals, Colonial Chemicals)
- Unit batch size: 50 L (in-house) to 10,000 L (vendor for Duratek LAW Plant)
- Required volume per test: 200 L to 42,500 L
- Total processed (2002-2007): 550,000 L (HLW) 130,000 L at VSL + 4 Million L at Duratek Pilot (LAW)
- Glass produced in pilot demonstrations:
  - 440,000 lbs (HLW)
  - 250,000 lbs at VSL + 7.7 million lbs at Duratek Pilot (LAW)
- Variability in Hanford Sample Compositions:

  LAW: AP-101, AZ-101, AZ-102, AN-102, AN-103, AN-104, AN-105, AN-107, AW-101, AP-101 combined with SY-104 and SY-101 combined with AP-104

  HLW: C-104, AY-102/C-106, AZ-101 and AZ-102

Issues in Shipping and Handling

- Importance of specifications (or lack thereof) in packaging size and container type
- Temperature variation and delay in transport leading to compaction, crystallization, settling and change in rheology
- Insufficient head space in shipping container to re-mix properly

Issues During Testing or Between Simulant Batches

- Consistency between feed batches: variations in both physical and chemical properties

Response: a “preview sample” was shipped overnight for preliminary testing before approval for delivery (acceptable recourse discrepancy has to be agreed upon as part of the procurement as large-scale batches are costly)

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Issues During Testing or Between Simulant Batches (cont'd)

- Synchronization between test sequence and delivery frequency - logistics

  Response: Delivery scale and storage capacity were increased

- Interruption of testing (e.g., pump failure overnight) leads to feed simulant settling and re-suspension issues

  Response: Equipment redundancy and back-up equipment to allow the feed to be re-mixed in steps.

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Issues During Testing or Between Simulant Batches (cont'd)

- Crystallization of LAW and HLW melter feeds which appeared minor at the bench scale, became a much larger problem (2 to 3 inch crystals) at pilot scale (50-gallon drums)

  Response: Avoid long-term storage of feed; keep the feed concentration within the given limits; external drum warmer was very successful in re-dissolving borate crystals

Other Issues

- Market depletion of certain chemicals (e.g., zircon no longer available following China entering WTO, vendor discontinuing an approved product)
- Need for appropriate substitutes when specified starting materials become unavailable