Low Temperature Aluminum Dissolution Plans for Sludge Batch 6 in Tank 51

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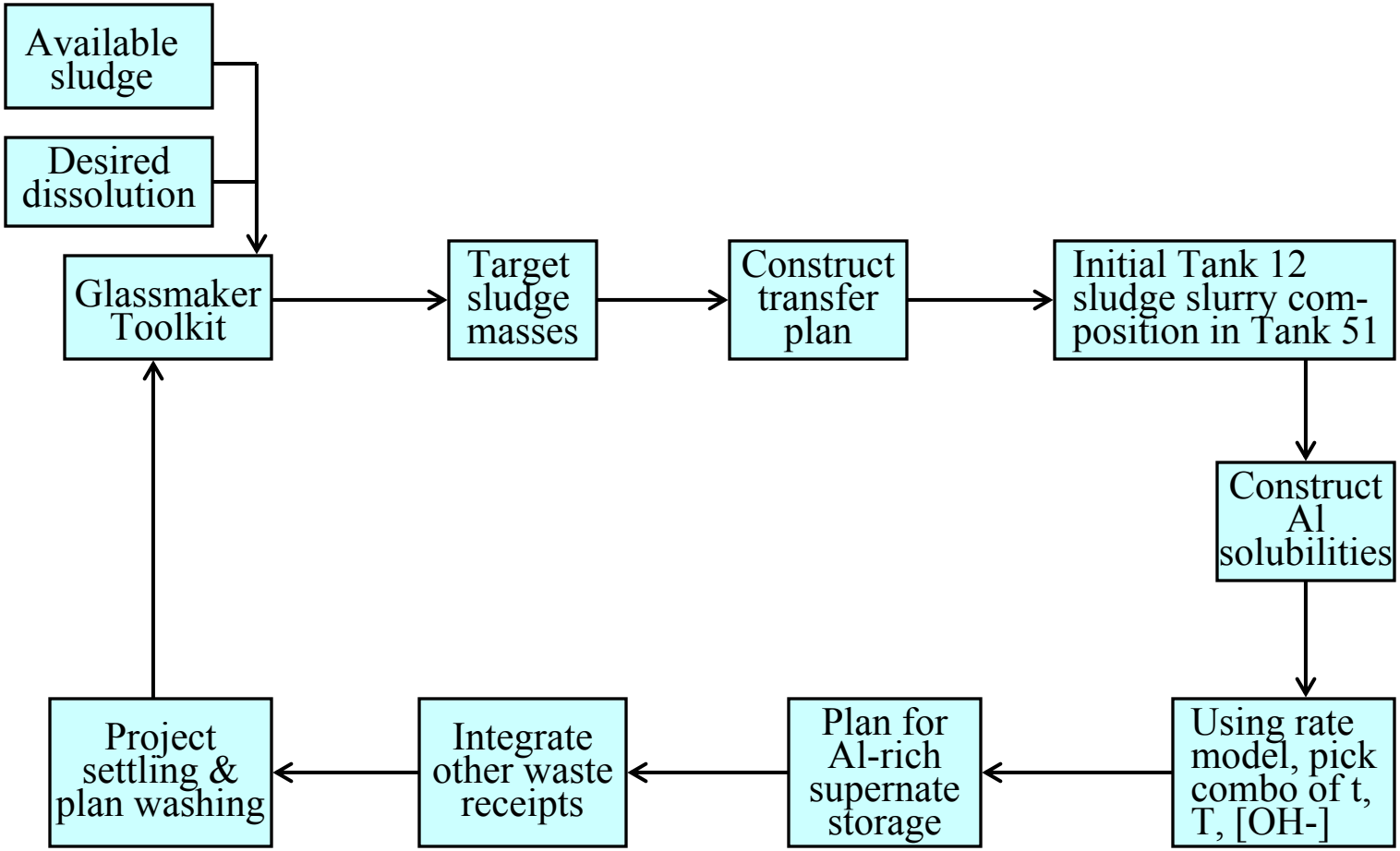
Differences Between SB5 and SB6 LTAD

	SB5	SB6 Plan
High Heat HM Sludge	Washed SB4 sludge (Tank 11) heel, 1.07 M [Na^+]	Unwashed Tank 12 sludge, 7.54 M [Na^+]
	106,000 kg Al solids of 191,000 kg, predominantly boehmite	143,000 kg Al solids of 194,000 kg, predominantly boehmite
	Added 129,000 gal of 50 wt% NaOH, to 4.08 M	Addition of 108,000 gal of 50 wt% NaOH, to 3.85 M
	46 days, 60 ^oC	40 days, 65-70 ^oC
	64% dissolution of Al solids	75% dissolution of Al solids
	Half of dissolved Al stored in Tank 11 (45 canisters worth), near half to saltcake storage	119 canisters worth to store in Tank 8. Removal from washing similar to SB5.
PUREX Sludge	50,000 kg solids from Tanks 5, 6, 7, and 8	50,000 kg solids from Tank 4

Approach to SB6 Planning



Initial Determination of Target Sludge Masses

- Available sludges are from Tank 12, and Tank 4.
- Analysis with Glassmaker Toolkit identified acceptable ratio of 180,000 kg of Tank 12 sludge to 50,000 kg of Tank 4 sludge, with 60 - 75% of Tank 12 aluminum dissolved.
- More dissolution is favored:
  - Reduces the amount of glass
  - Allows more sludge to be washed in a batch.

SB6 Transfer Plan

- **Three 12-51 transfers to put 180,000 kg in Tank 51.**

- **Projected Tank 12 interstitial composition from samples and history.**
  - Evaporation
  - CO_2 absorption, OH- depletion
  - NO_2 depletion by radiolysis

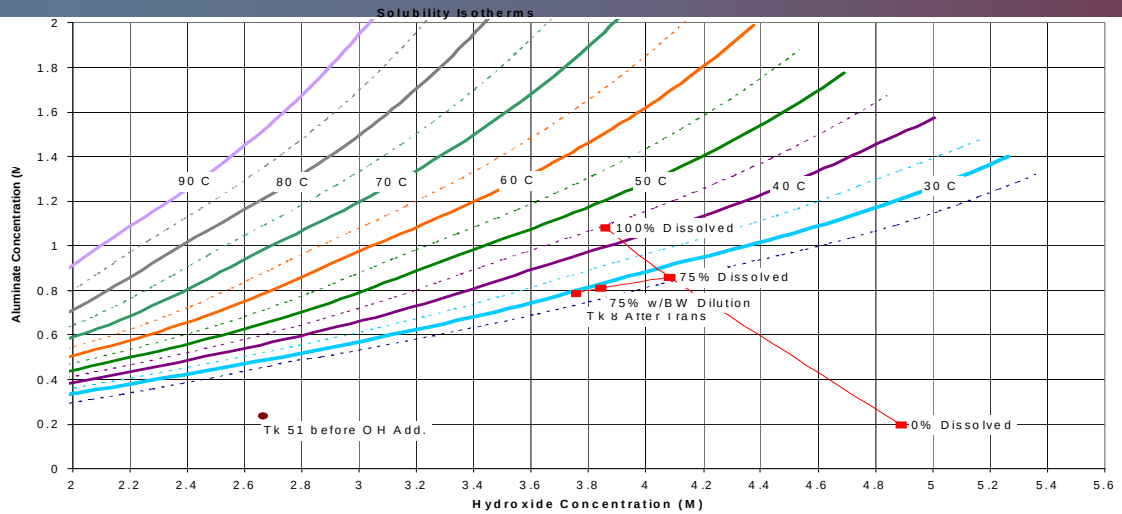
- **Use Tank 24 liquid to suspend Tank 12 solids.**
  - More than planned needed to reduce yield stress.
  - High [Na+], [OH-]
  - Low [AlO_2-]

- **Decant of 51 supernate to Tank 12 to limit aluminate solution volume to store.**
  - Begin NaOH addition after decant.

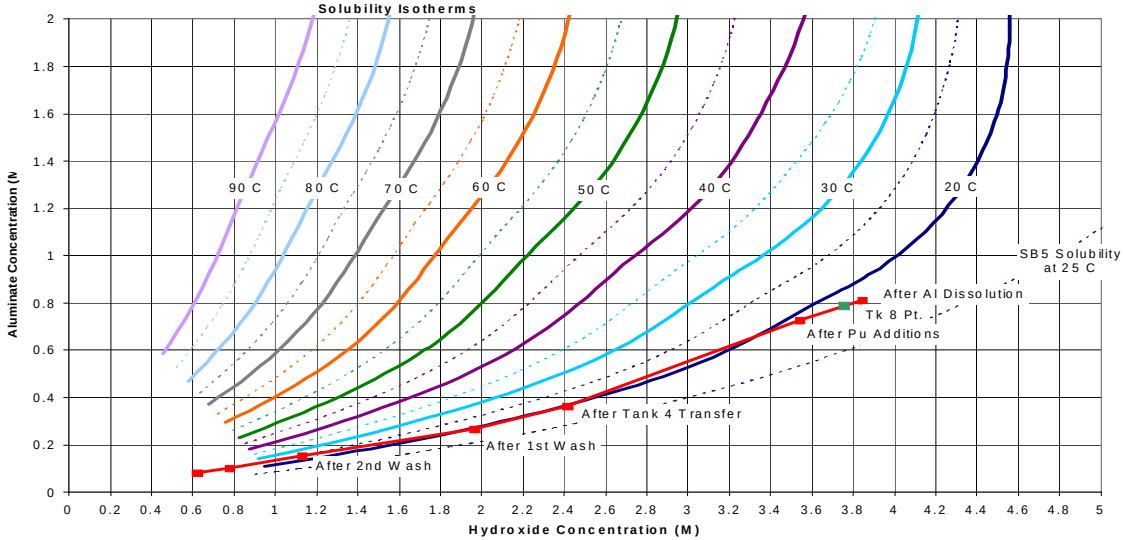
SB6 Transfer Plan (Continued):

- After Al dissolution, have allotted maximum of 30 days to settle.
- Accommodate sampling.
- Add Tank 4 sludge after Al dissolution and decant is complete.
- Dilute, mix, settle, decant, repeat - to target composition.

Aluminum Solubilities



Boehmite Solubility [J. Pike]



Gibbsite Solubility [J. Pike]

Dissolution Rate

$$t = \frac{\alpha F(wf,\alpha)}{(\eta^0 \gamma_{\pm}^{1/2} A)\sqrt{C_{OH}^0}} e^{\frac{14800}{T}}$$

[A. Pajunen]

where

t = Dissolution time, hr

$$F(wf,\alpha) = \frac{1}{\sqrt{\alpha(\alpha-1)}} \mathrm{Ln}\left|\frac{(\sqrt{\alpha}-\sqrt{\alpha-1})(\sqrt{\alpha-1+wf}+\sqrt{\alpha-1})}{(\sqrt{\alpha}+\sqrt{\alpha-1})(\sqrt{\alpha-1+wf}-\sqrt{\alpha-1})}\right|$$

α = Mole ratio at initial conditions of free OH ion in the liquid phase relative to Al in the solid phase, dime

C_{OH}^0 = Initial liquid phase concentration of free OH ion in molal units, gmol/kg water

T = Dissolution operating temperature, K

wf = Weight fraction of initial Al remaining in solids at the conclusion of the dissolution process, dimensio

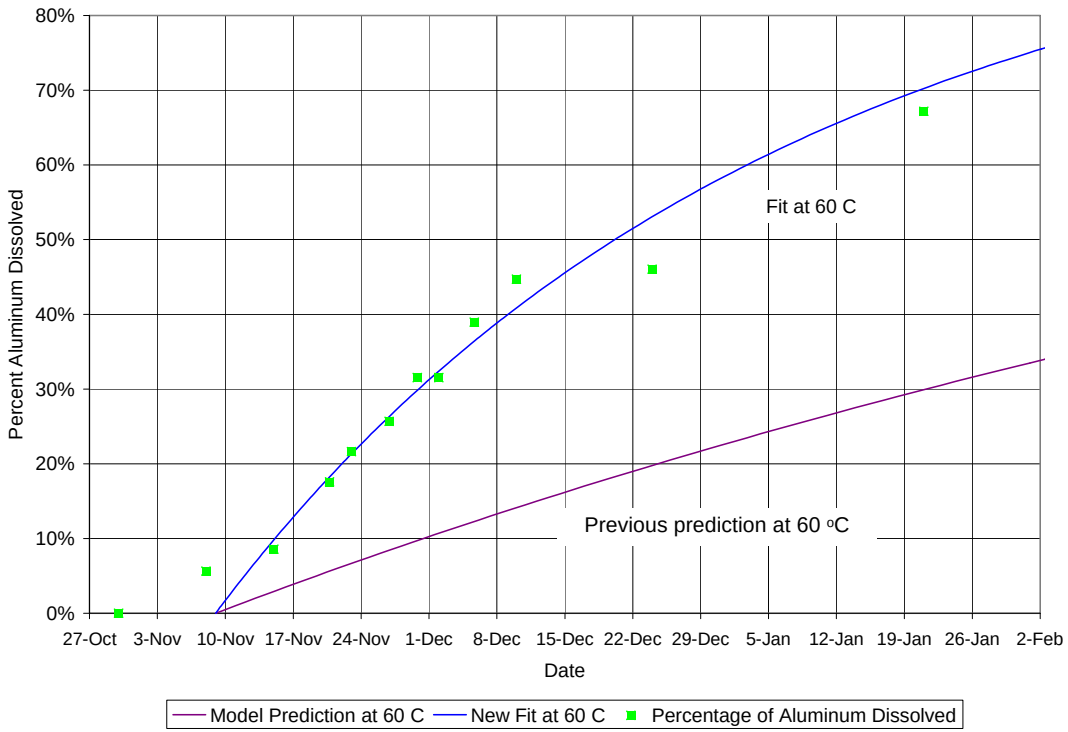
η^0 = the initial specific surface area of aluminum hydroxide solids, m^2/gmol Al

$\gamma_{\pm}$ = Constant defined in the batch dissolution model development equivalent to variation of ${}_{25}a_{NaOH}$, activity of NaOH in water at 25°C, with free OH molality for the liquid phase where ${}_{25}a_{NaOH} \sim \gamma_{\pm}C_{OH}$, dimensionless.

A = Boehmite dissolution reaction pre-exponential rate constant, mol Al-m^{-2}-hr^{-1}-(mol OH/kg water)^{½}

Projecting SB6 Dissolution Rate:

$$\eta\gamma_{\pm}^{1/2} A = 7E15$$



SB5 Dissolution in Tank 51 (~60 °C) [J. Pike]

Heat-up and Dissolution

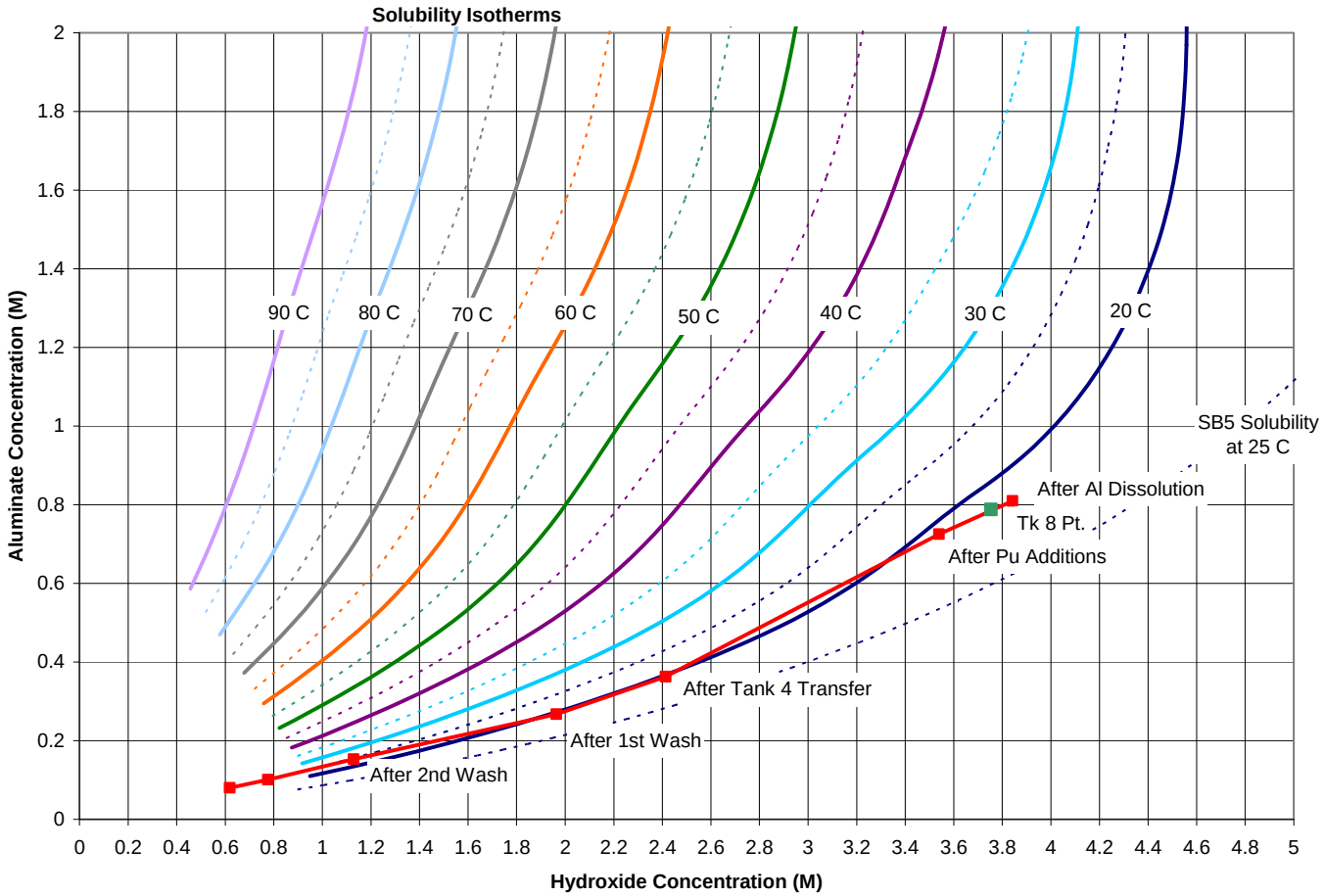
Other inputs:

- Radiolytic Heat similar to SB6
- Caustic dilution provides ~8 ^{o}C
- Temperature rise from slurry pumps: 1.7 ^{o}C/day/pump for 2nd, 3rd, 4th pump.
- Initial planning estimated 40 days for caustic addition and 4-pump heating to 65 ^{o}C for dissolution.
- Additional calculation indicates that early start of slurry pump operation during caustic addition, and operation of 3 pumps at 90% utility to 70 ^{o}C would achieve dissolution in the same period.

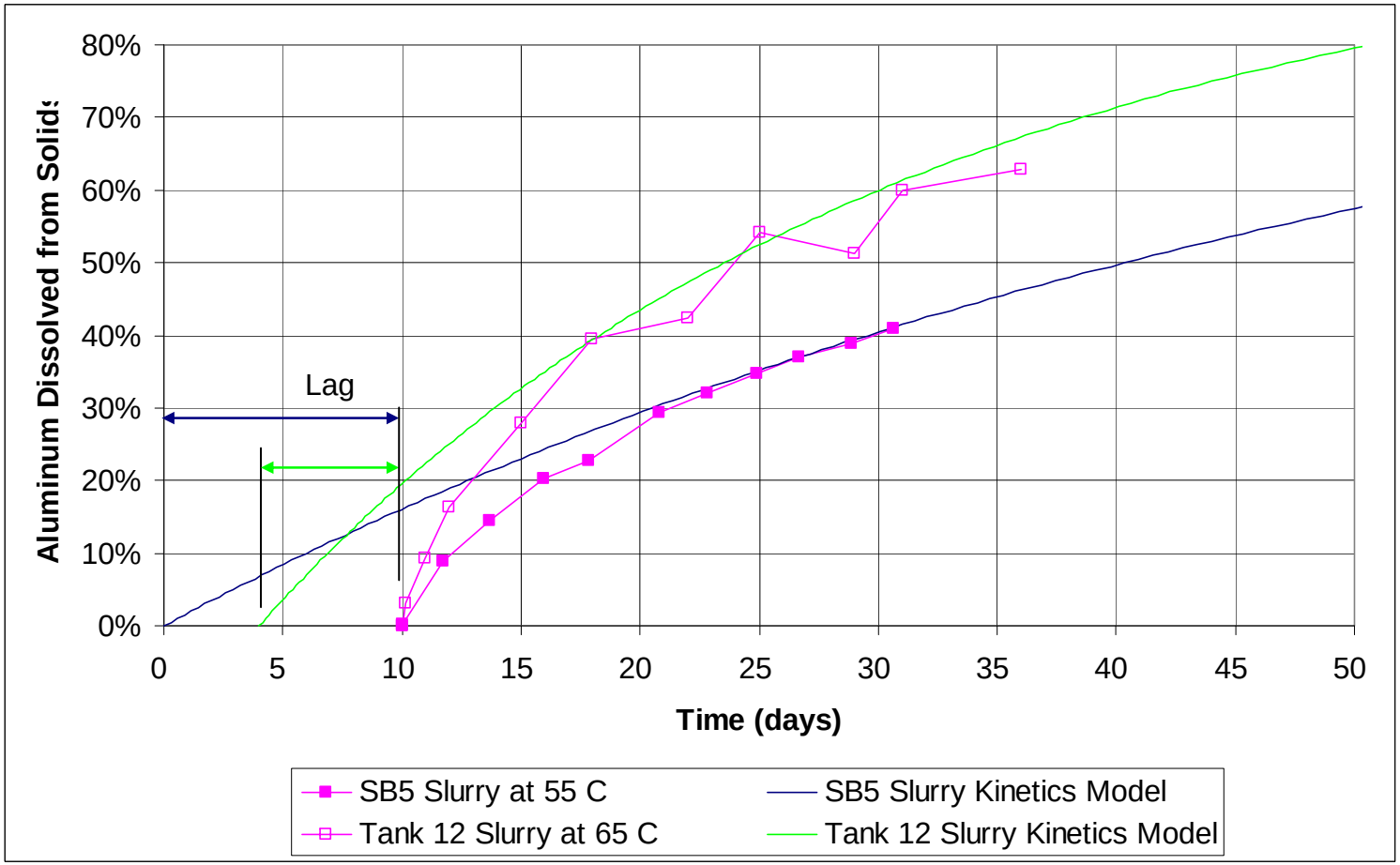
SB6 Prep after LTAD

- Settle for up to 30 days and decant Al-rich supernate to Tank 8
- Receipt of Tank 4 sludge, and Qualification sampling
- Repeated dilution, mixing, settling, and decanting to remove salt.
- First two washes need supplementary NaOH addition.
- Settling rate is a key to match washing steps to Evaporator capacity.

Supplementary Slide – NaOH for Washing



Supplementary Slide – Laboratory Dissolution



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Real Waste Lab Demonstrations of Low Temperature Aluminum Dissolution (LTAD)

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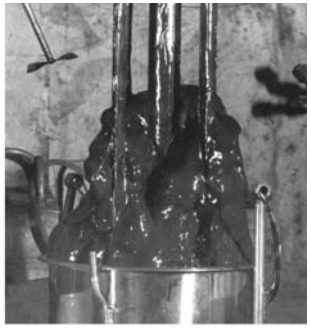
May 20, 2009



USDOE Office of Waste Processing Technical Exchange

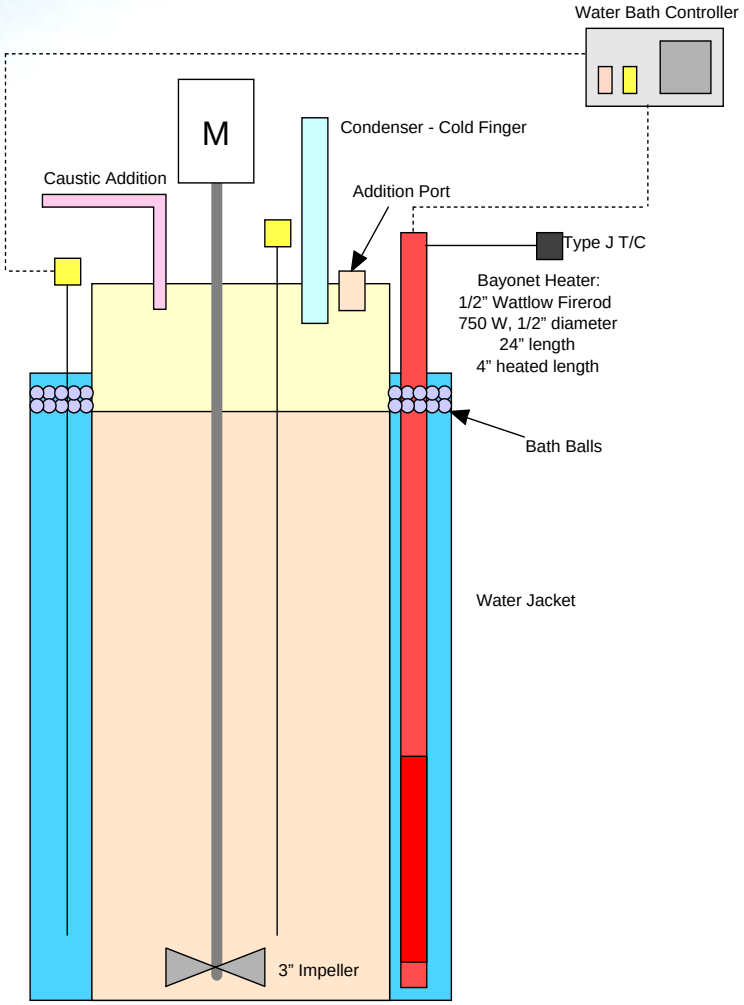
Background

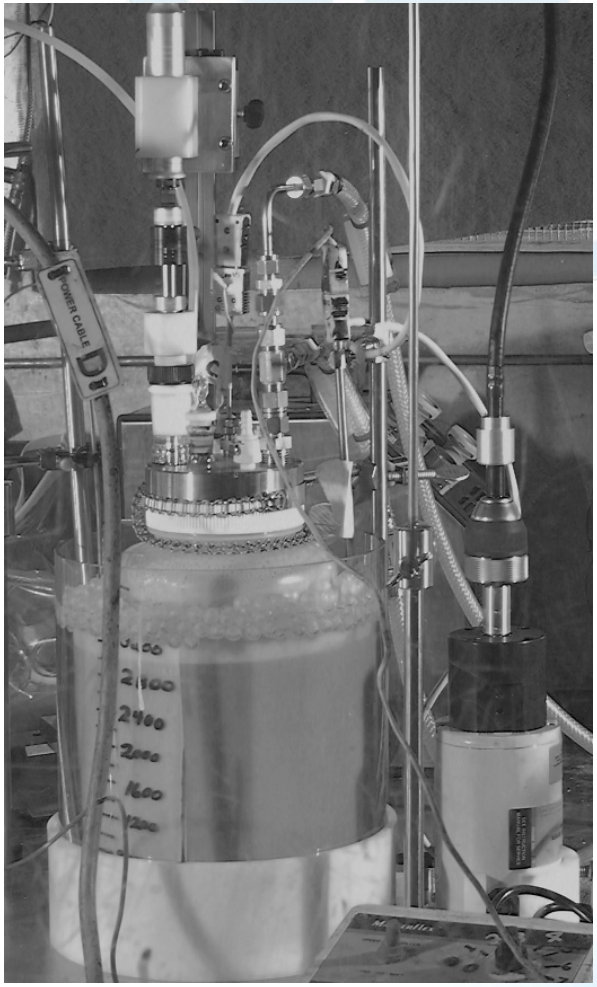
- **Sludge vitrified in glass at DWPF**
- **Goal: minimize glass production**
- **1982 in-tank demo @ 85 ºC**
- **<85 ºC called "low temp"**
- **Recent LTAD lab demos**
  - Assess dissolution effectiveness
  - Identify potential problems

Lab Demonstration Conditions

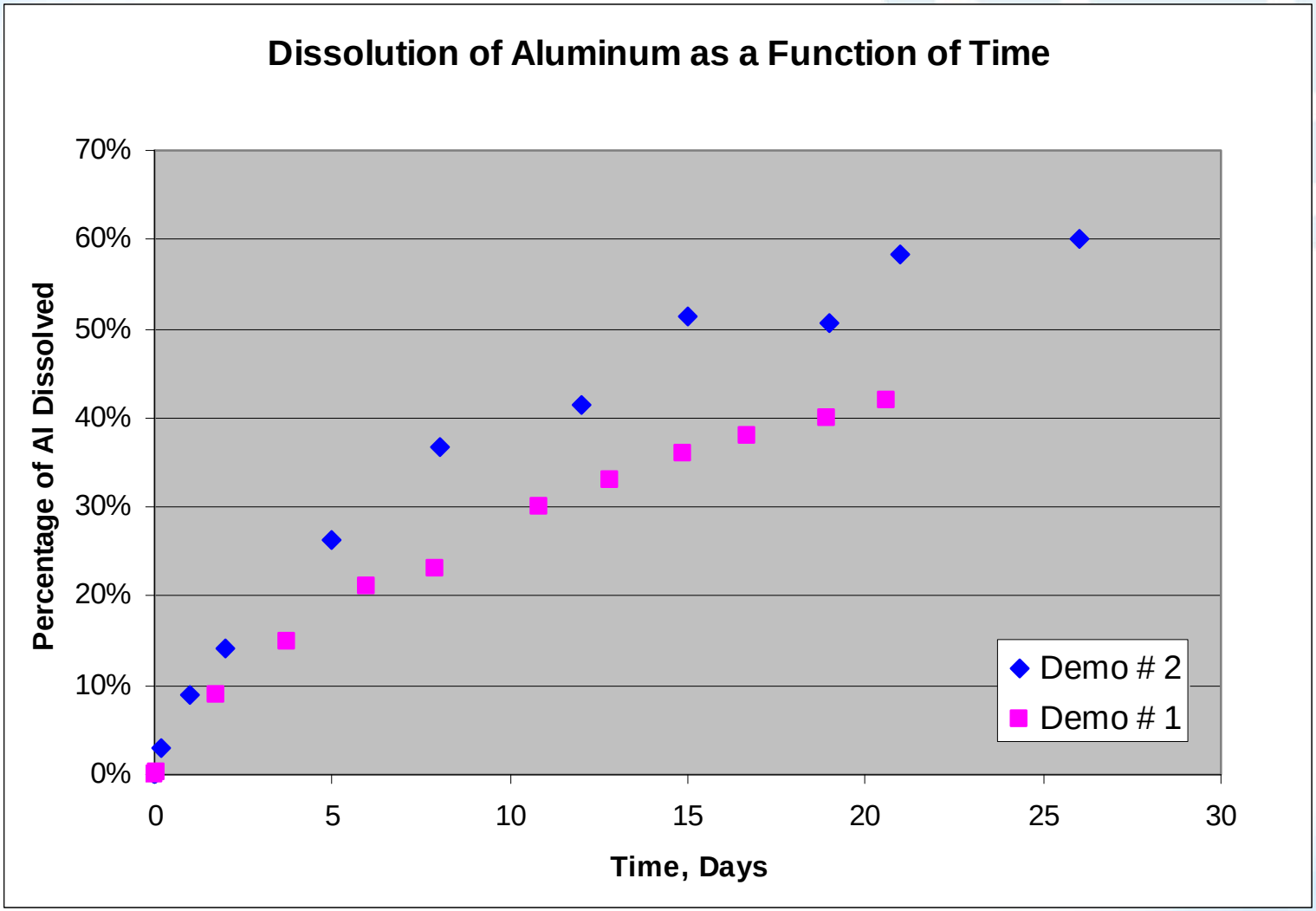
Descriptor	Demo #1	Demo #2
Primary sludge source	SRS Tk 11	SRS Tk 12
Sludge batch identification	SB5	SB6
Sludge status	Washed	Unwashed
Slurry density	1.08 g/mL	1.35 g/mL
Insoluble solids content	9.4 wt%	7.2 wt%
Al content of insoluble solids	~25 wt%	~40 wt%
Primary form of Al	Boehmite	Boehmite
Al to Fe mass ratio	2:1	10:1
Dissolution temperature	55 ºC	65 ºC
OH^-_{free} to Al_{ins} molar ratio at t=0	5:1	4:1

Dissolution Labware





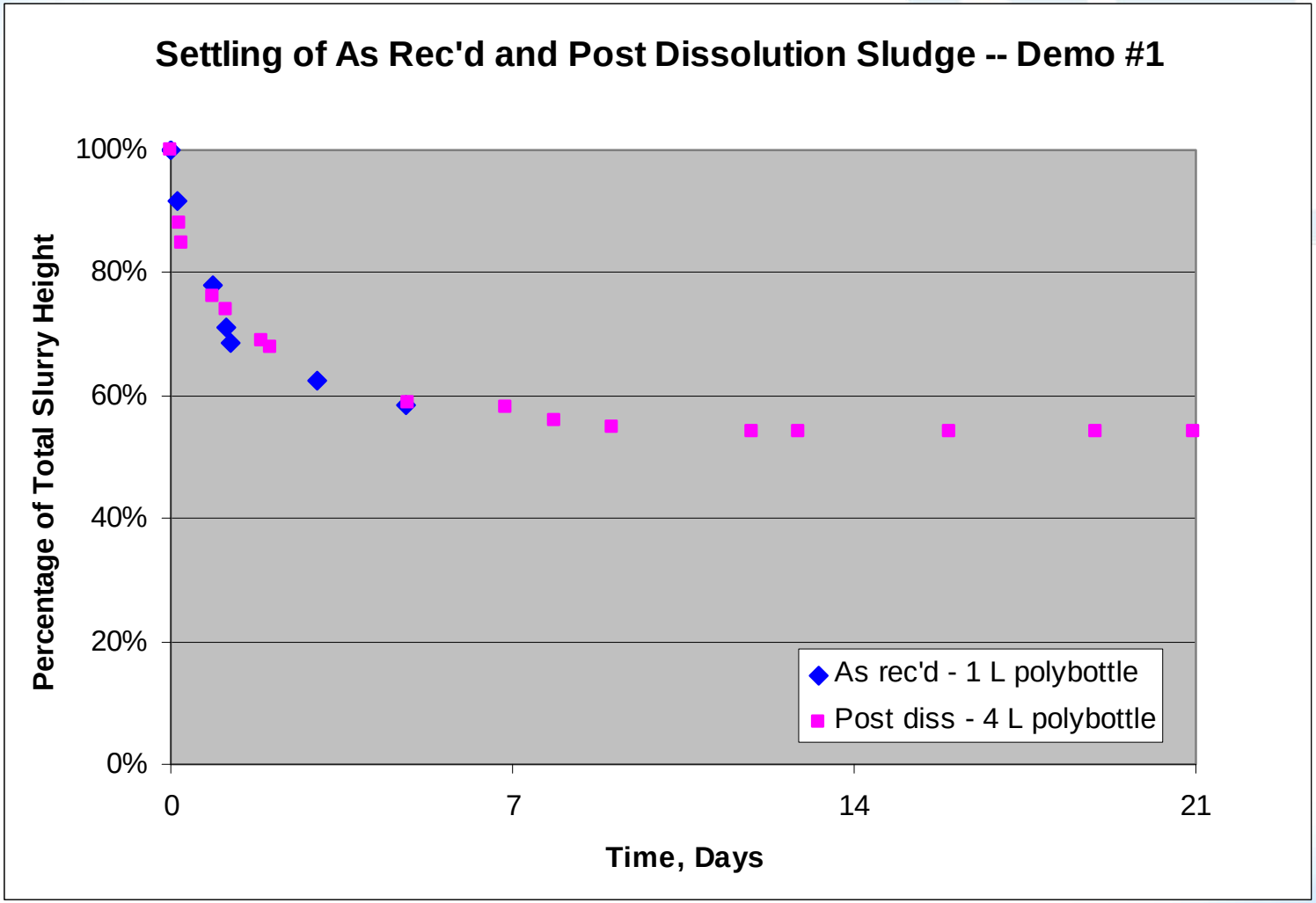
Dissolution Results



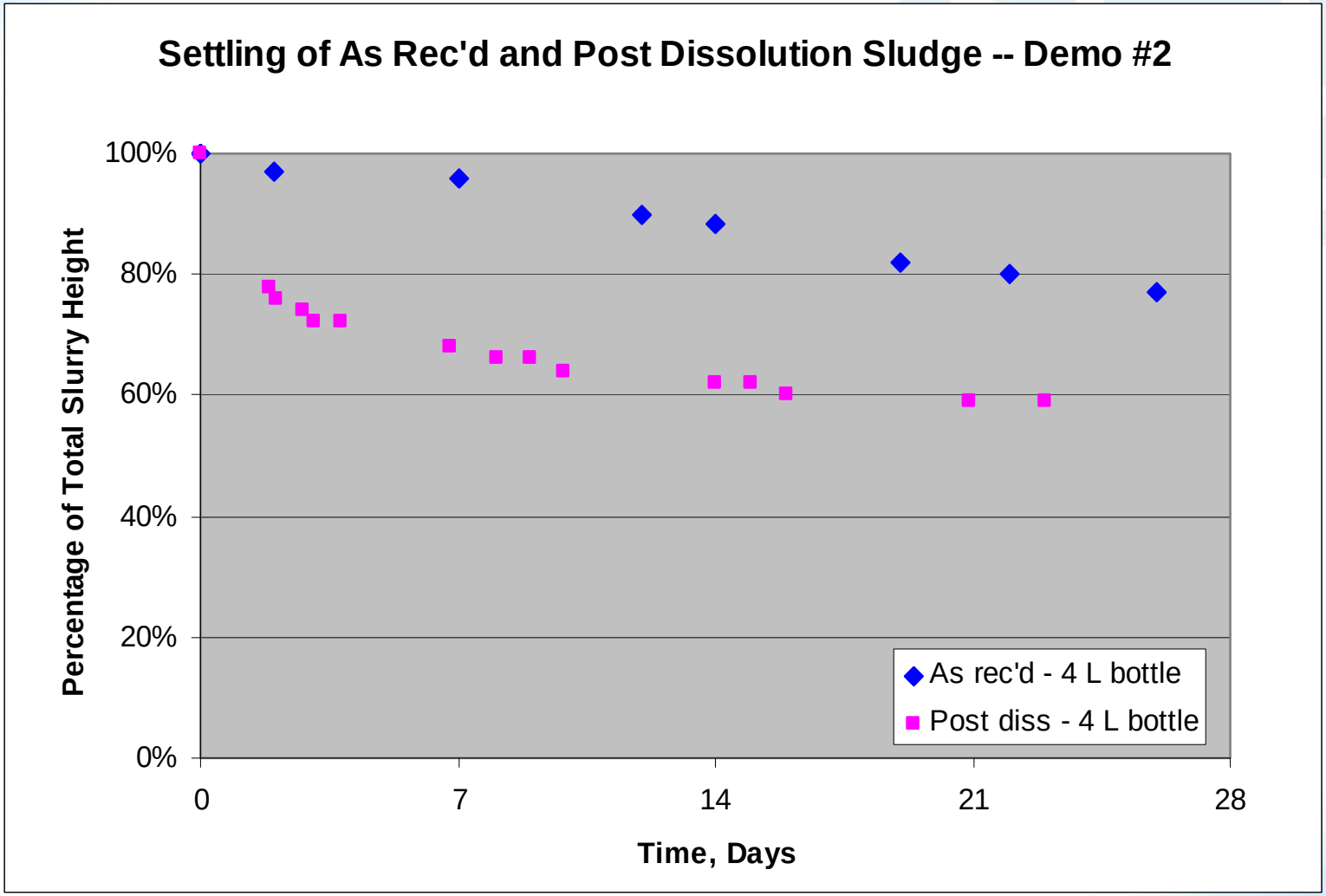
Rheology

Demo Number	Sample Descriptor	Yield Stress, Pa	Plastic Viscosity, cP	Wt% Insoluble Solids
1	As rec'd	5.8	7.6	9.4
	Post diss	9.2	19	6.4
2	As rec'd	19	27	7.2
	Post diss	2.5	27	4.4

Settling Behavior – Demo #1



Settling Behavior – Demo #2



Conclusions

- **Effectively dissolved about half of boehmite**
- **Greater aluminum dissolution possible**
- **Rheology and settling effects dependent on waste**
  - Additional data will aid understanding

Further Lab Testing

- **Particle size and rheology measurements as a function of:**
  - Aluminum content
  - Solids distribution
  - Presence/absence of aluminum dissolution

Questions?

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