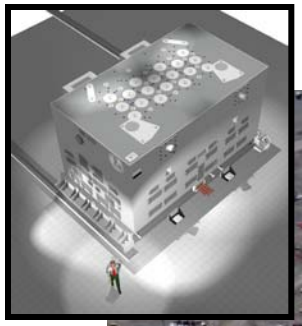
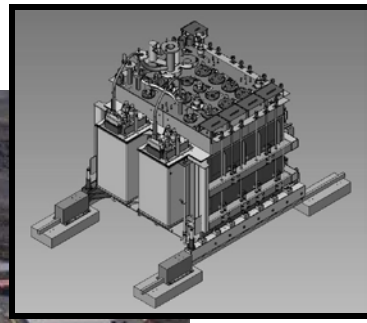
Improving Sodium and Aluminum Loadings in WTP Glass

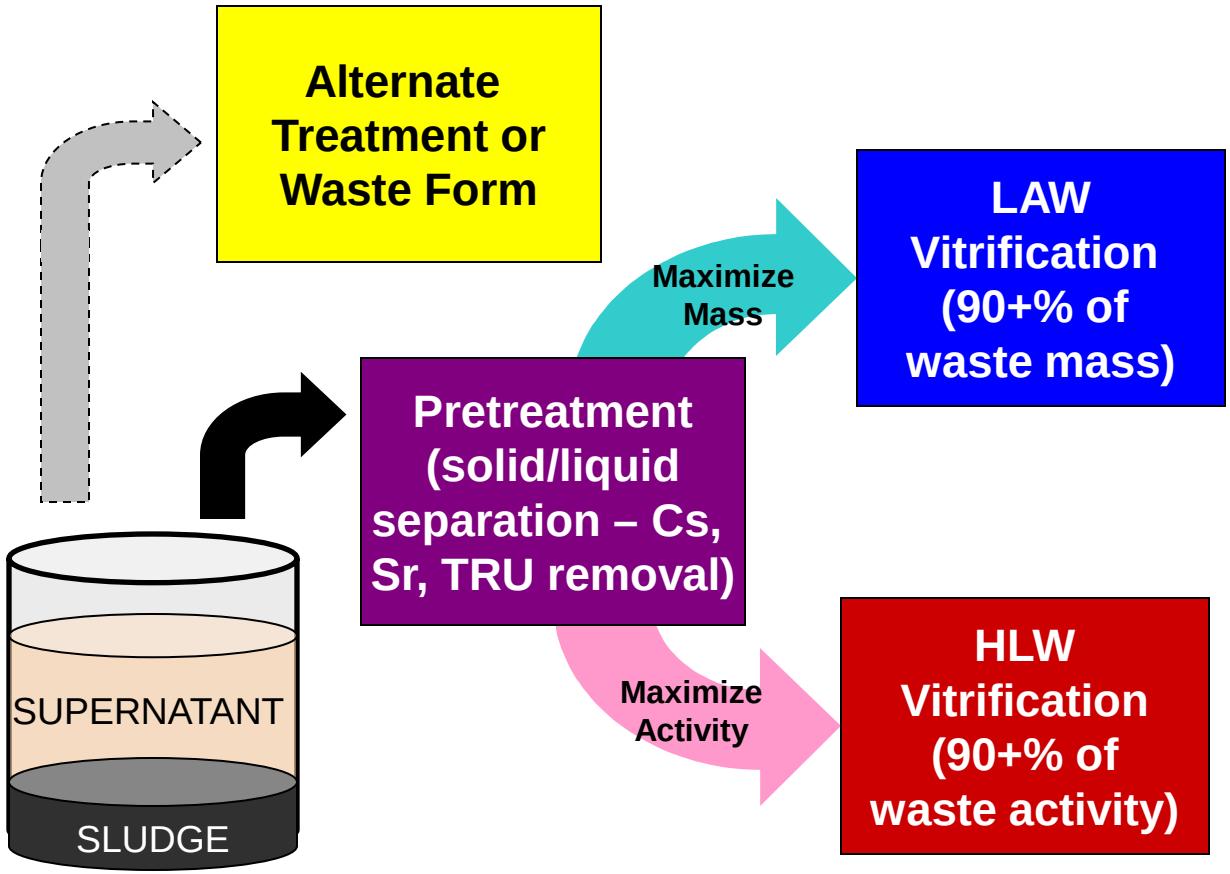
Brad Bowan





February 8, 2010

WTP Flow Sheet – Key Process Flows



- Meet WAC
- Maximize Waste Loading
- Manage Sulfate
- Manage Halides
- Glass Product Stays at Hanford

- Meet WAC
- Maximize Waste Loading
- Maximize Melter DF's
- Manage Noble Metals
- Glass Product Ships to National HLW Repository

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HLW/LAW Vitrification Enhancements

- Increased *waste loading* reduces canister count and increases waste treatment rate
  - Enhanced glass formulations, crystal management, higher temperature
- Increased *melt rate* increases waste treatment rate
  - Enhanced glass formulations, melt pool agitation (bubblers), higher temperature

Waste Treatment Rate = **Glass Production Rate** X **Waste Loading in Glass**

↓

Primarily limited by crystallinity for HLW, sulfur and sodium for LAW

Na/Al Management through increased glass loadings

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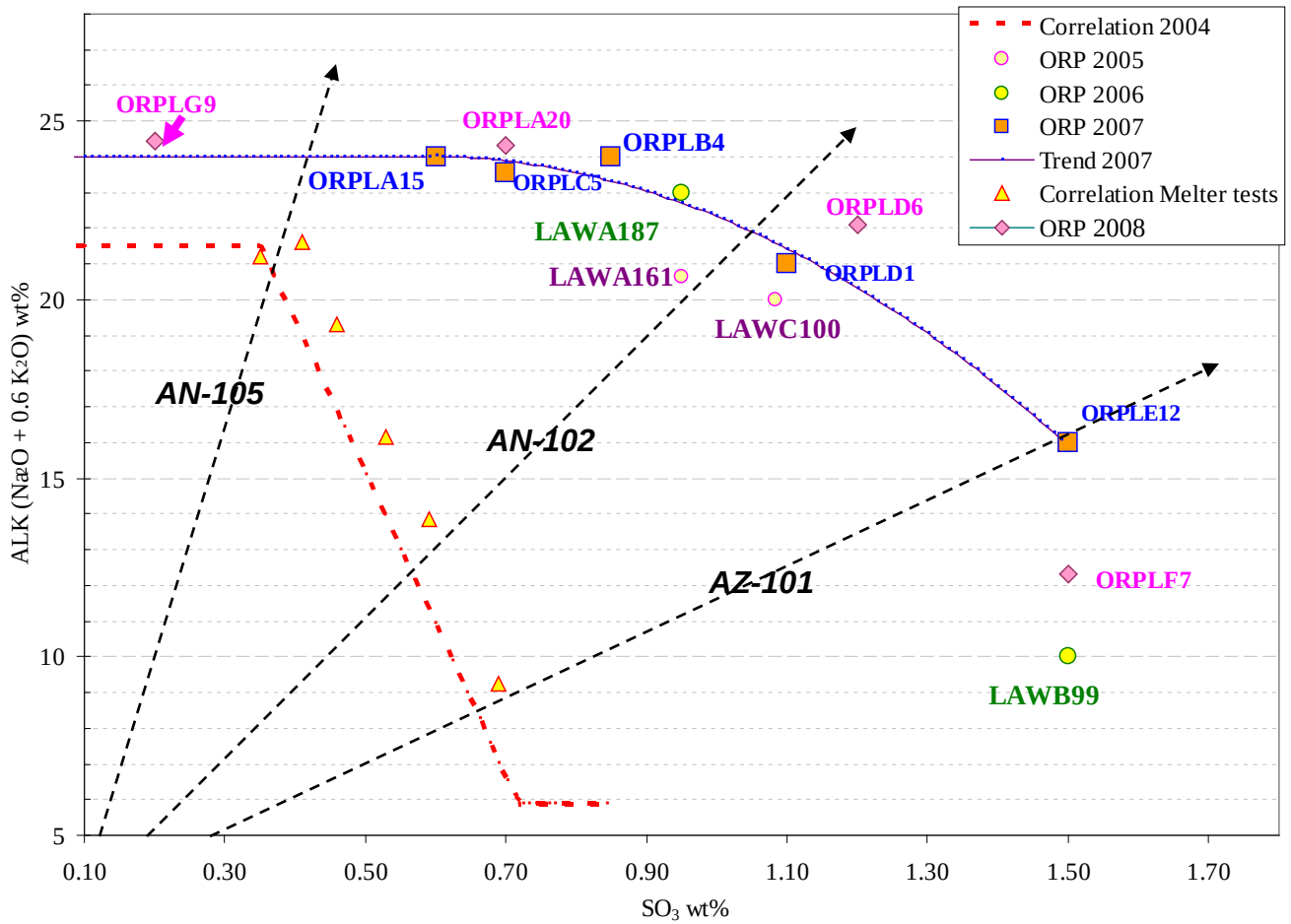
LAW – Improve Sulfate and Sodium Incorporation

ORP: 2005 – 2009 Results: Increased LAW Loadings



LAW sulfate and sodium optimization results: Hanford will produce ~35% LESS LAW glass – corresponding reduction in operating time or required LAW treatment capacity.

Waste ID	Bechtel Baseline Loadings			Bechtel Correlation (2007)			ORP (2006) Loadings			ORP (2007) Loadings			ORP (2008) Loadings		
AN-105	Glass LAWA44	26.0%	Waste	Glass LAWE4H	27.2%	Waste	Glass LAWA187	30.5%	Waste	Glass ORPLA15	31.6%	Waste	Glass ORPLA20	31.6%	Waste
		20.0%	Na_2O		21.3%	Na_2O		22.9%	Na_2O		24.0%	Na_2O		24.0%	Na_2O
		0.5%	K_2O		0.5%	K_2O		0.5%	K_2O		0.5%	K_2O		0.5%	K_2O
		0.2%	SO_3		0.4%	SO_3		1.0%	SO_3		0.6%	SO_3		0.7%	SO_3
AP-101	Glass LAWA126	24.5%	Waste	Glass LAWE3	25.4%	Waste							Glass ORPLG9	29.1%	Waste
		18.5%	Na_2O		18.2%	Na_2O								21.0%	Na_2O
		3.8%	K_2O		5.0%	K_2O								5.8%	K_2O
		0.4%	SO_3		0.4%	SO_3								0.2%	SO_3
AN-107	Glass LAWC22	16.2%	Waste	Glass LAWE5H	20.6%	Waste				Glass ORPLB4	26.2%	Waste			
		14.4%	Na_2O		19.0%	Na_2O					24.0%	Na_2O			
		0.1%	K_2O		0.5%	K_2O					0.1%	K_2O			
		0.4%	SO_3		0.5%	SO_3					0.9%	SO_3			
AN-104	Glass LAWA137	20.0%	Waste	Glass LAWE6H	20.9%	Waste				Glass ORPLC5	31.0%	Waste			
		14.6%	Na_2O		15.8%	Na_2O					23.6%	Na_2O			
		0.3%	K_2O		0.5%	K_2O					0.5%	K_2O			
		0.4%	SO_3		0.5%	SO_3					0.7%	SO_3			
AN-102	Glass LAWC35	14.0%	Waste	Glass LAWE7H	16.2%	Waste	Glass LAWC100	24.1%	Waste	Glass ORPLD1	24.9%	Waste	Glass ORPLD6	25.9%	Waste
		12.0%	Na_2O		13.5%	Na_2O		20.0%	Na_2O		21.0%	Na_2O		22.0%	Na_2O
		0.1%	K_2O		0.5%	K_2O		0.2%	K_2O		0.2%	K_2O		0.2%	K_2O
		0.6%	SO_3		0.6%	SO_3		1.1%	SO_3		1.1%	SO_3		1.2%	SO_3
AZ-101	Glass LAWB83	7.3%	Waste	Glass LAWE9H	11.3%	Waste				Glass ORPLE12	19.8%	Waste			
		5.5%	Na_2O		8.9%	Na_2O					16.0%	Na_2O			
		0.2%	K_2O		0.5%	K_2O					0.6%	K_2O			
		0.7%	SO_3		0.7%	SO_3					1.5%	SO_3			
AZ-102	Glass LAWB96	3.7%	Waste	Glass LAWE10H	6.2%	Waste	Glass LAWB99	11.9%	Waste				Glass ORPLF7	14.3%	Waste
		5.5%	Na_2O		5.7%	Na_2O		10.0%	Na_2O					12.0%	Na_2O
		0.1%	K_2O		0.5%	K_2O		0.4%	K_2O					0.5%	K_2O
		0.7%	SO_3		0.8%	SO_3		1.5%	SO_3					1.5%	SO_3

Progress in LAW Loading Enhancements

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Crystallization in HLW Glasses

- Crystallization is the primary waste loading limiting factor for HLW
  - Processability – Melter tolerance to crystals and crystal management strategy (T_L vs. $T_{1\%}$)
  - Product quality – Nepheline formation for high-Al streams
    - Need for improved nepheline discriminator
- The limiting crystal phases typically incorporate several waste consitutuents
  - E.g., Spinels (Fe, Cr, Ni, Mn, Al, Mg…), nepheline (Al, Si, Na), other aluminosilicates (Al, Si, Na, K, Ca, Mg, Fe…), phosphates (P, Ca, Li…), etc.
- Limits are highly dependent on interactions between glass components, not simply single-component limits

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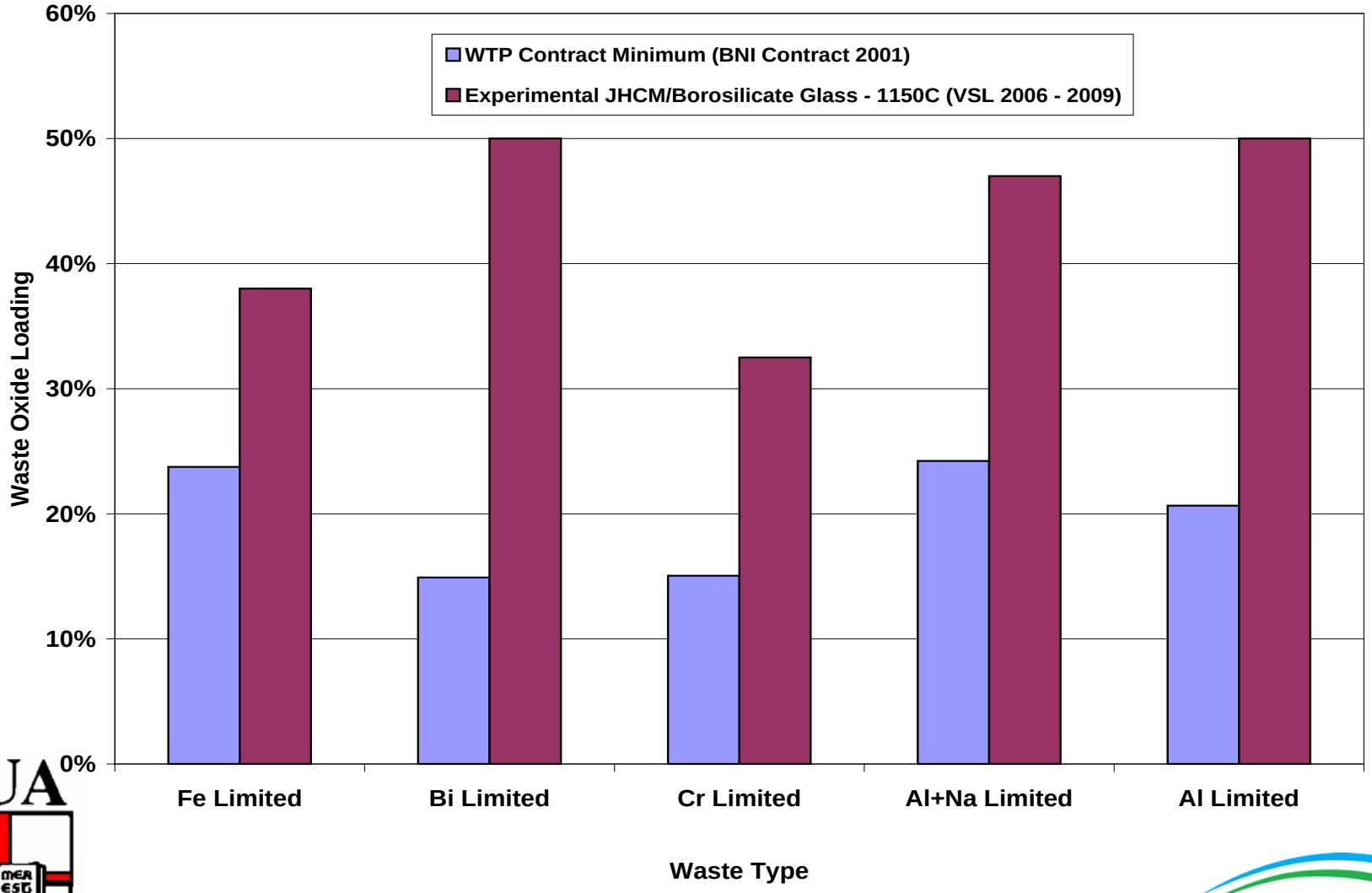
Improvements in HLW Waste Loading from 2001 to 2009

Demonstrated Waste Loading Improvements can Result in 4500 less HLW canisters



WTP High Aluminum HLW Streams

- Significant fraction of Hanford HLW streams are limited by Al
  - Nepheline is typically the primary limitation
  - Spinel is still a frequent secondary limitation
  - Spinel $T_{1\%}$ tends to increase with increasing Al
- Drives HLW canister count, mission duration, caustic leaching, Na additions, and LAW treatment capacity requirements
- Higher HLW glass Al loadings provides for system flexibility in trading off leaching in PT vs incorporation in HLW glass

Higher Al loading in HLW glass:

- **Reduces HLW glass volume and HLW mission duration**
- **Reduces Na additions for Al leaching, reducing LAW feed**

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Cumulative Distribution of Aluminum in WTP HLW Feed

TFCOUP, Rev 6

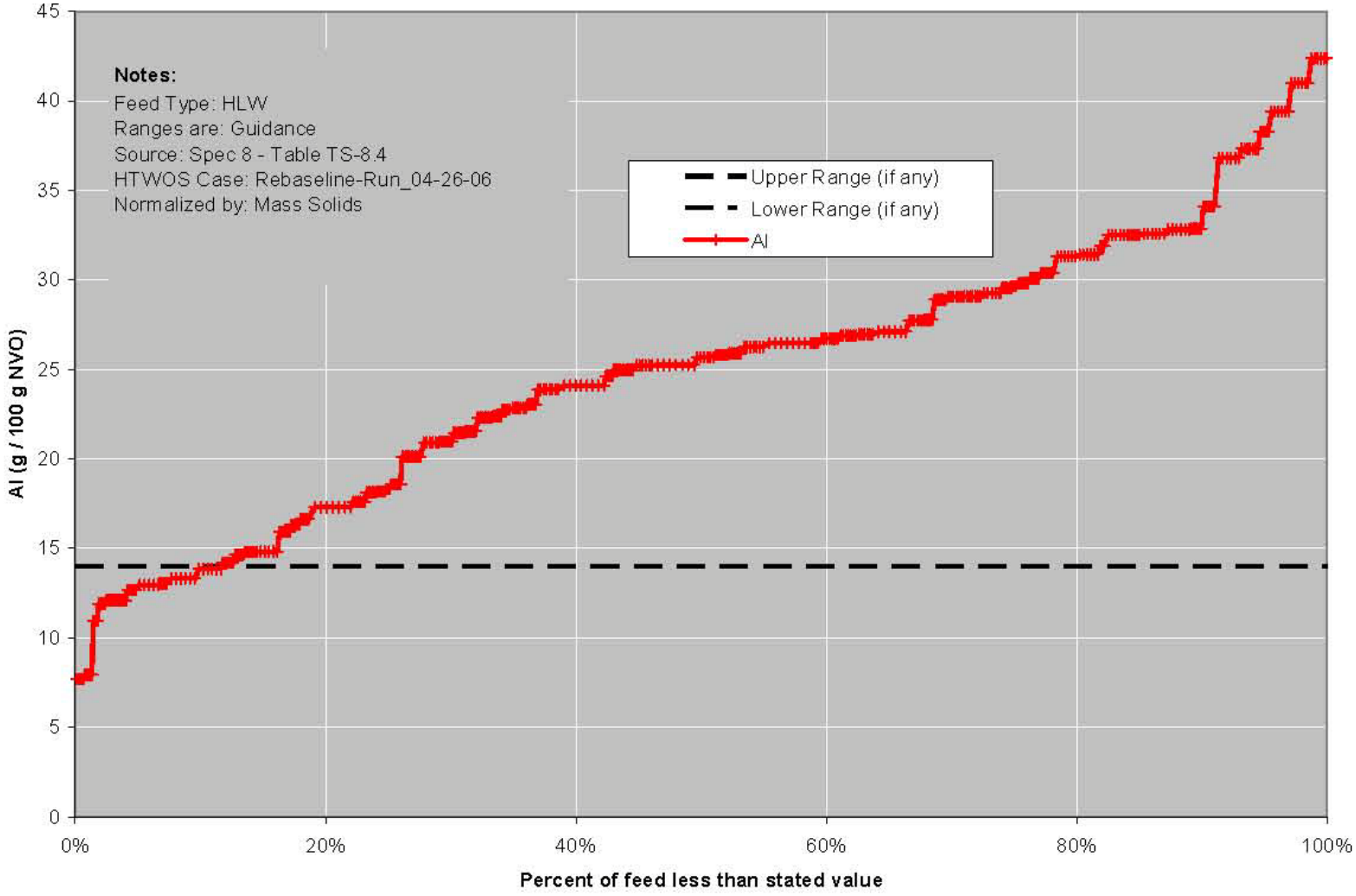
Wt% Al_2O_3

76%

57%

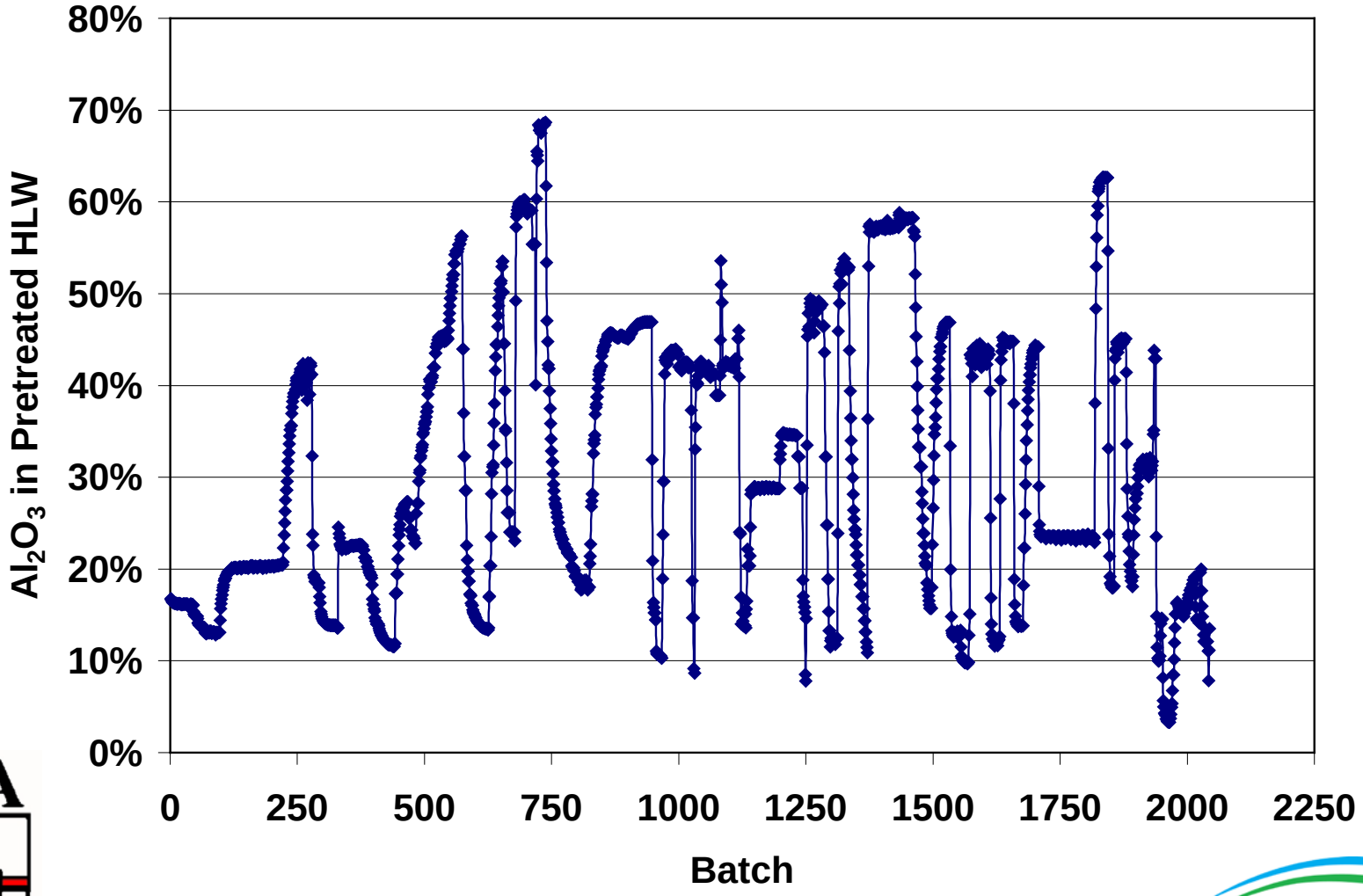
38%

19%



Alumina Content in WTP Pretreated HLW Feeds

Per TF COUP Rev. 6



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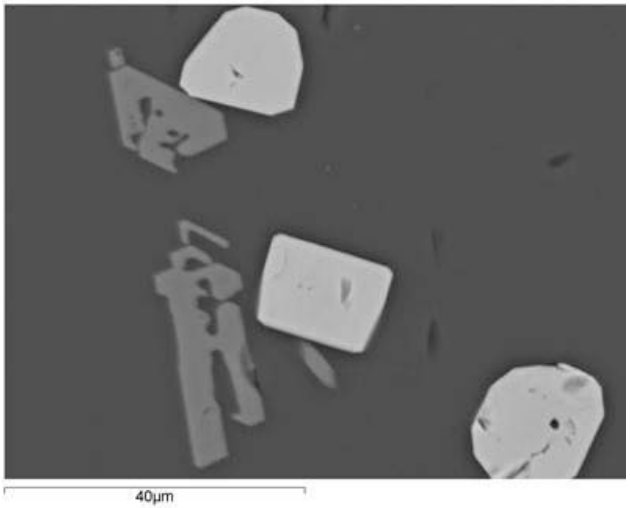
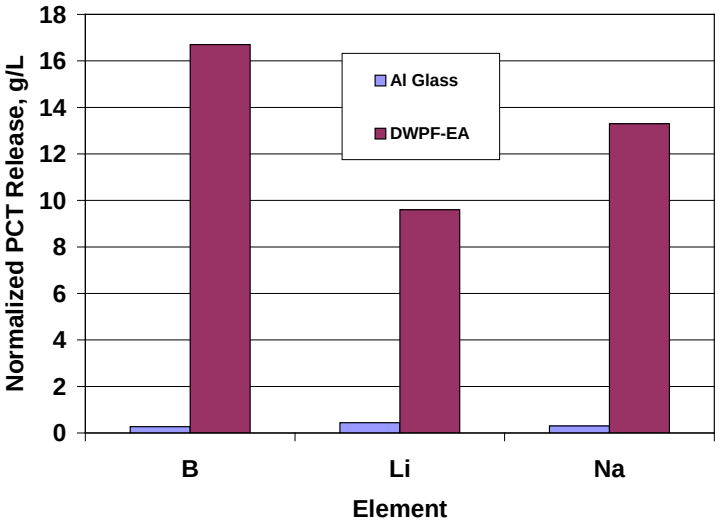
Initial Glass Formulations for Aluminum-Limited HLW

- Waste loadings from 35 to 55% investigated
- Crystallization *during canister cooling* is principal waste loading limiting factor
  - Massive ingrowth of Na-Al-Si phases (e.g., nepheline) is possible
  - Can cause failure to meet PCT
- Optimized formulation with 45% waste loading meets all product quality and processing requirements

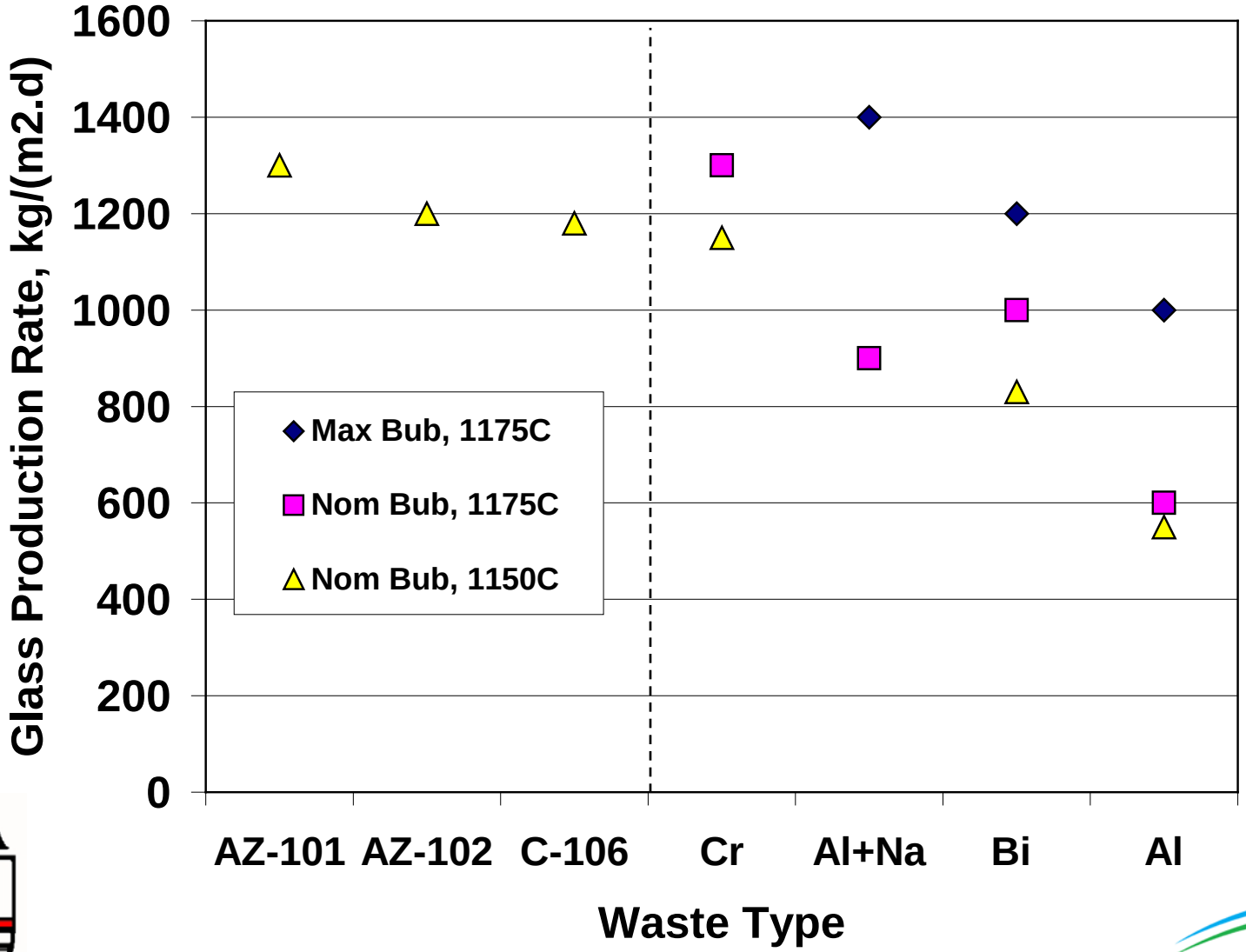




45% waste loading (24 wt% Al_2O_3)

DM100 Glass Production Rates

Effects of Waste Composition



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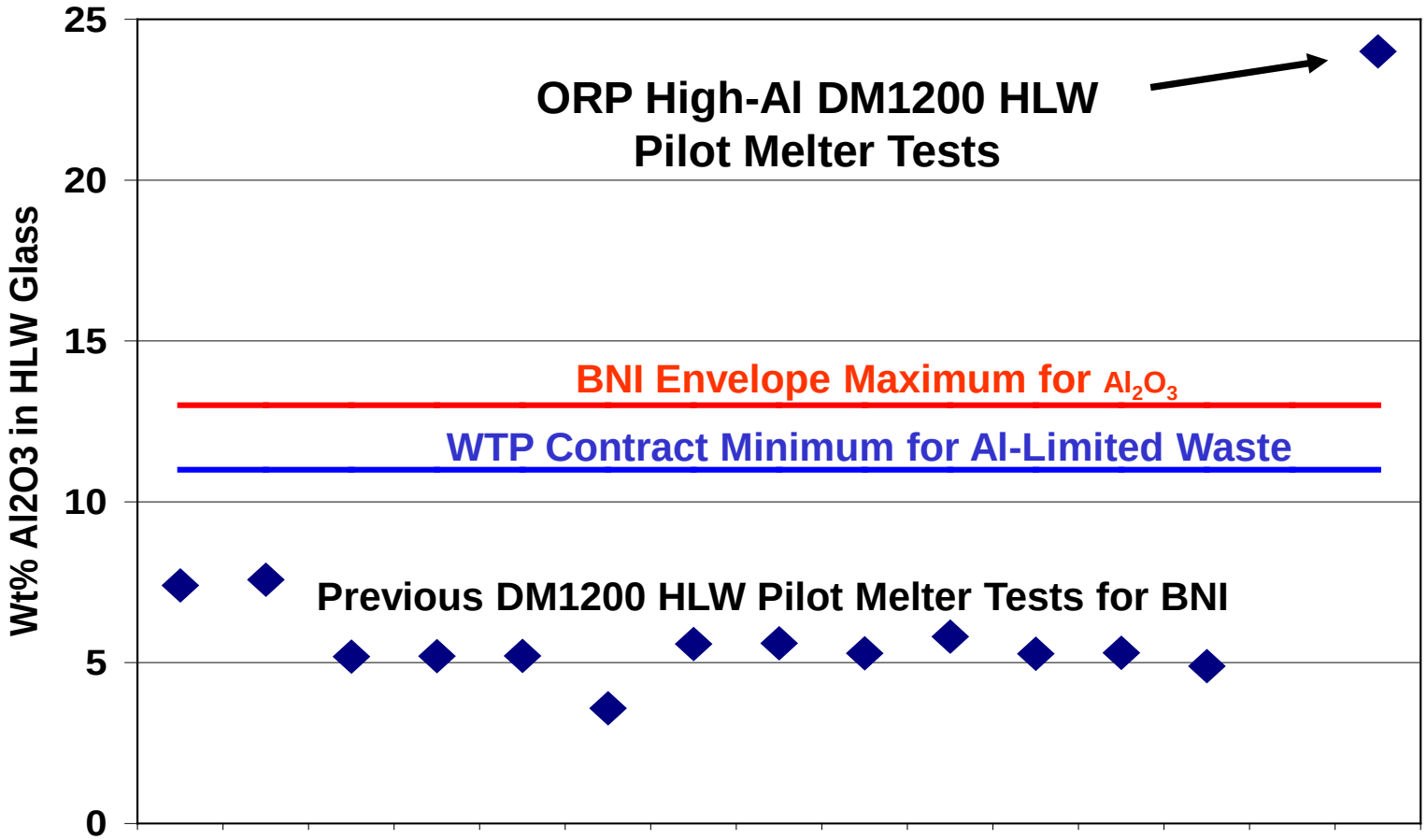
Increased Aluminum Loading in WTP HLW Glasses Demonstrated on One-Third-Scale Vitrification System



Demonstrated potential to double WTP HLW aluminum treatment capacity with no increase in HLW glass produced.

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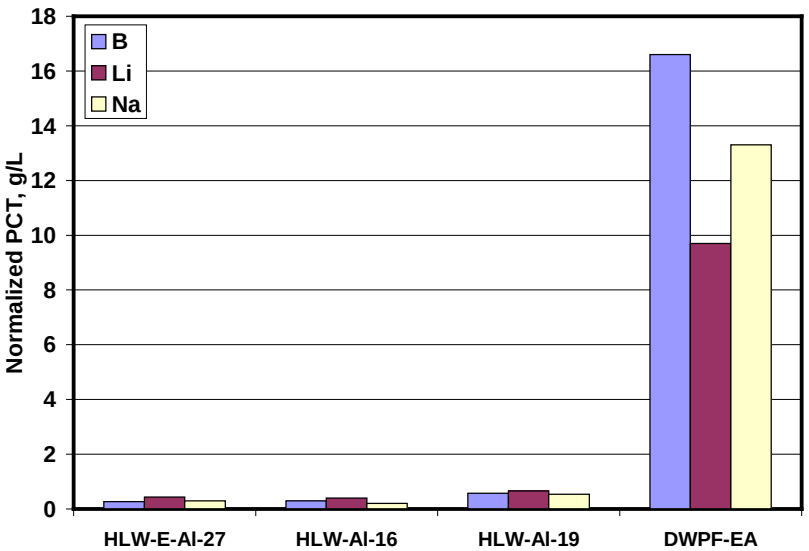
Melt Rate Improvement for WTP High-Al HLW Formulations

- Early high-Al formulations showed slow melt rates
- Rapid melt rate screening tests and improved formulations developed
  - Confirmed increased melt rates in DM100 melter tests
  - Maintained 24 wt% Al_2O_3 loading
  - Met all processing and product quality requirements

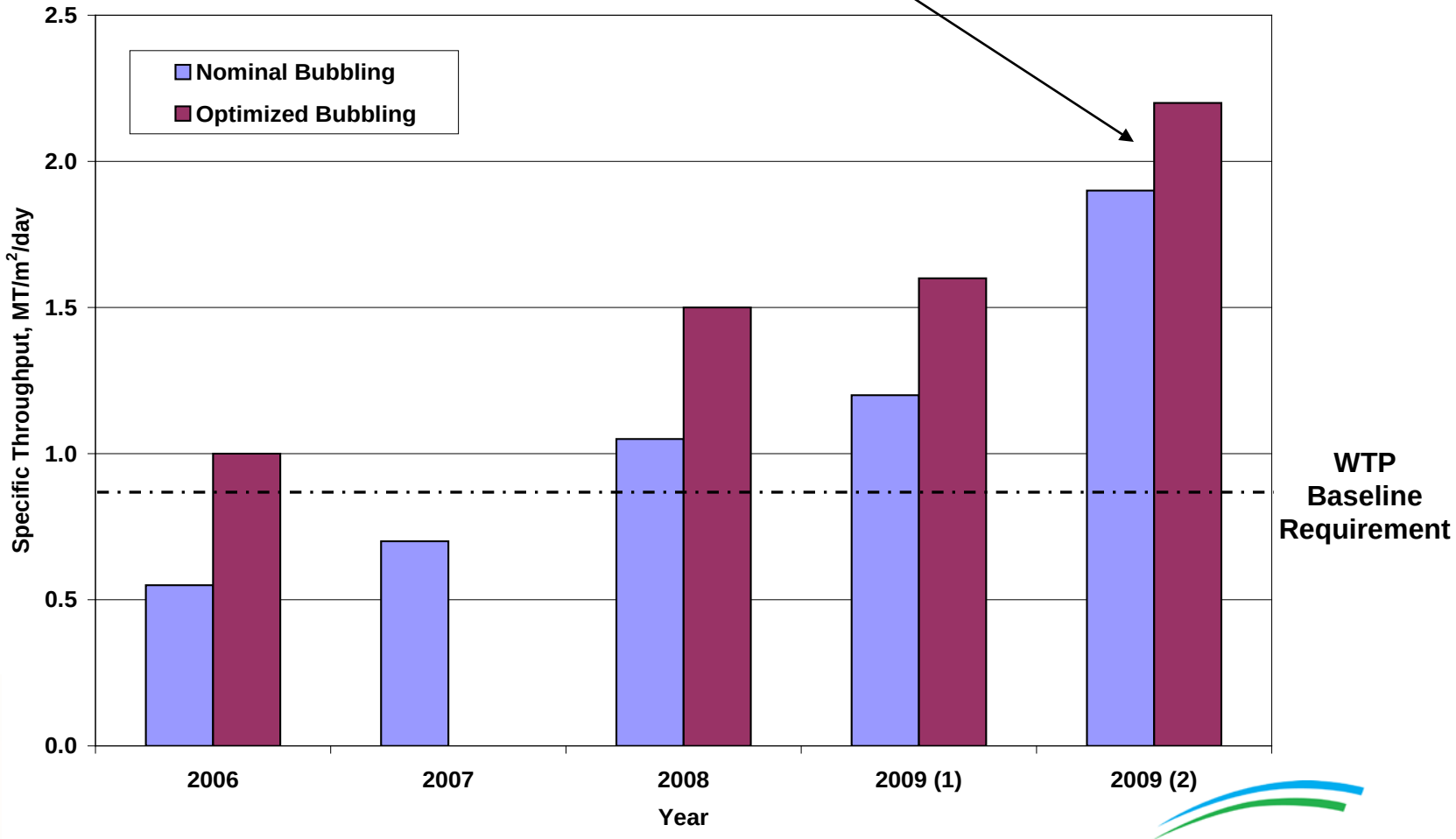


- Validated on DM1200 HLW Pilot Melter with integrated off-gas system
  - Test 1: 1150°C, 124 lpm bubbling 1500 kg/(m^2.d)
  - Test 2: 1150°C, 71 lpm bubbling 1050 kg/(m^2.d)
  - Test 3: 1175°C, 48 lpm bubbling 1050 kg/(m^2.d)
  - WTP Target: 800 kg/(m^2. d)

Source: VSL-08R1360-1, VSL-07R-1010-1

Progress in High-Al HLW Glass Formulations for WTP

- Waste loading increased to 50% **(26.6 wt% Al_2O_3)**; *And*
- Glass production rate further increased:



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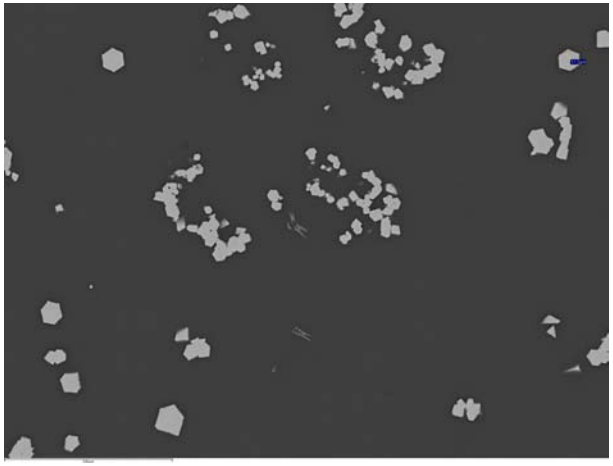
WTP High-Al HLW Glass with High Loading *and* High Melt Rate

- **50% waste loading; 26.6 wt% Al_2O_3**
- **Very high melt rate (> 2X baseline requirement)**
- **Meets all product quality requirements**
- **Processability demonstrated in continuous melter runs**



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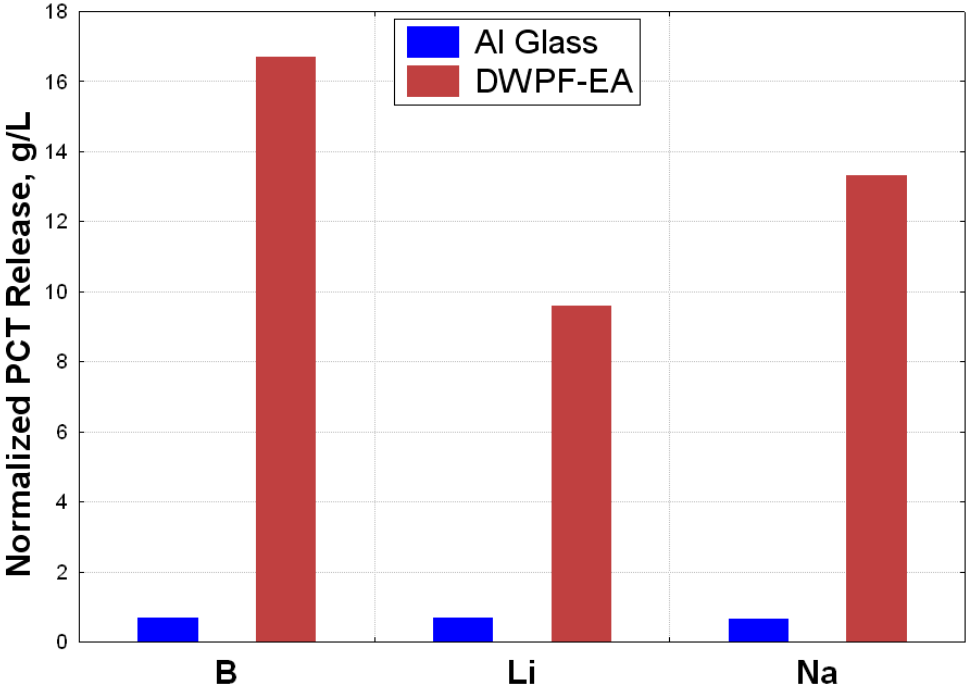

50% waste loading (26.6 wt% Al_2O_3)

Summary

- Combined improvements (thus far) in LAW sulfate and sodium Incorporation can result in significant reduction of LAW glass production (~200,000 MT)
- Sodium oxide loadings in glass of ~25 wt% are possible for low sulfate wastes
- Improvements (thus far) in HLW waste loadings can result in a reduction of 4500 HLW canisters
- Aluminum oxide loading in glass of 26.6 wt% with no deterioration in melter production rate is possible
- Continued improvement in waste loadings can substantially shorten the Hanford tank waste treatment mission, reduce the amount of glass produced, and save $ billions

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Acknowledgements

- This work was support by funding from the Department of Energy, Office of River Protection
- ORP staff
- Staff of the Vitreous State Laboratory at The Catholic University of America and Energy*Solutions*, Inc.