Near Tank Treatment System

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What is Near Tank Treatment System

- Continuous Sludge Leaching
- Near Tank Cesium Removal
- Caustic Recovery – Covered by a separate talk

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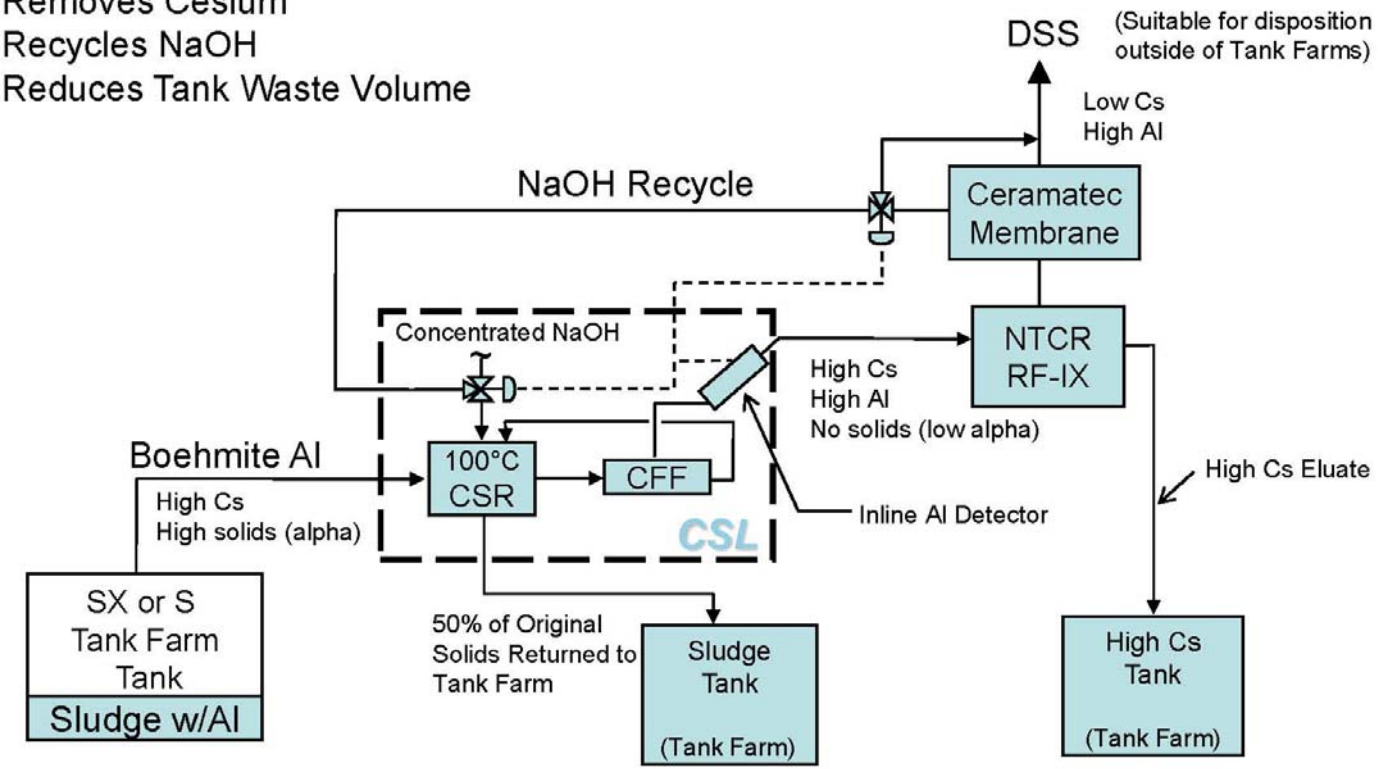
What is Near Tank Treatment System

- Removes Boehmite Al
- Removes Cesium
- Recycles NaOH
- Reduces Tank Waste Volume



CFF – Cross Flow Filter
CSL – Continuous Sludge Leaching
NTCR – Near Tank Cesium Removal
CSR – Continuously Stirred Reactor
DSS – Decontaminated Salt Solution
RF-IX – Resorcinol Formaldehyde – Ion Exchange

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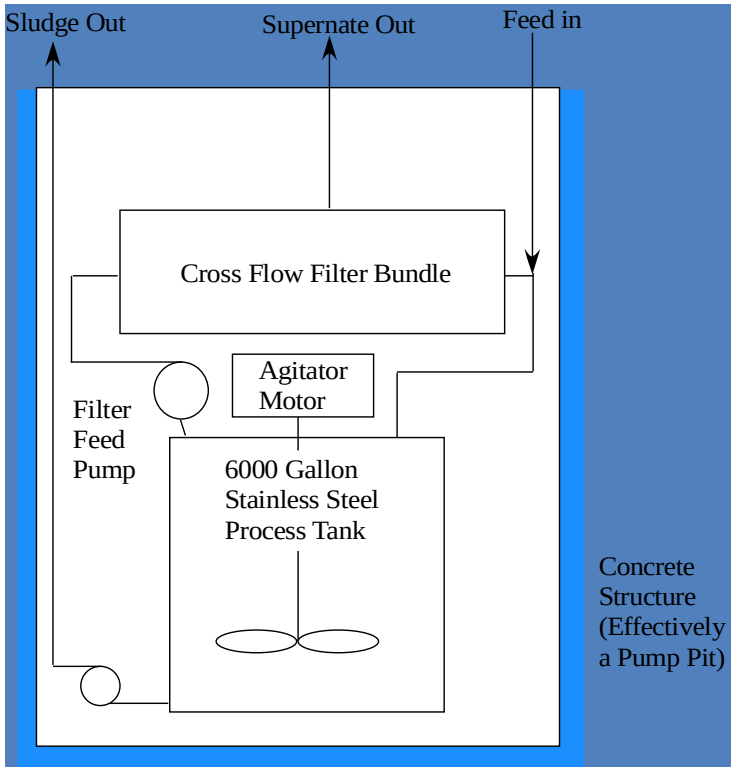
What is Continuous Sludge Leaching (CSL)

- Continuous Stirred Reactor with two discharge streams
  - One stream discharging a 10 wt% slurry stream of HLW leached solids
  - One stream discharging filtered leachant destined for LAW glass



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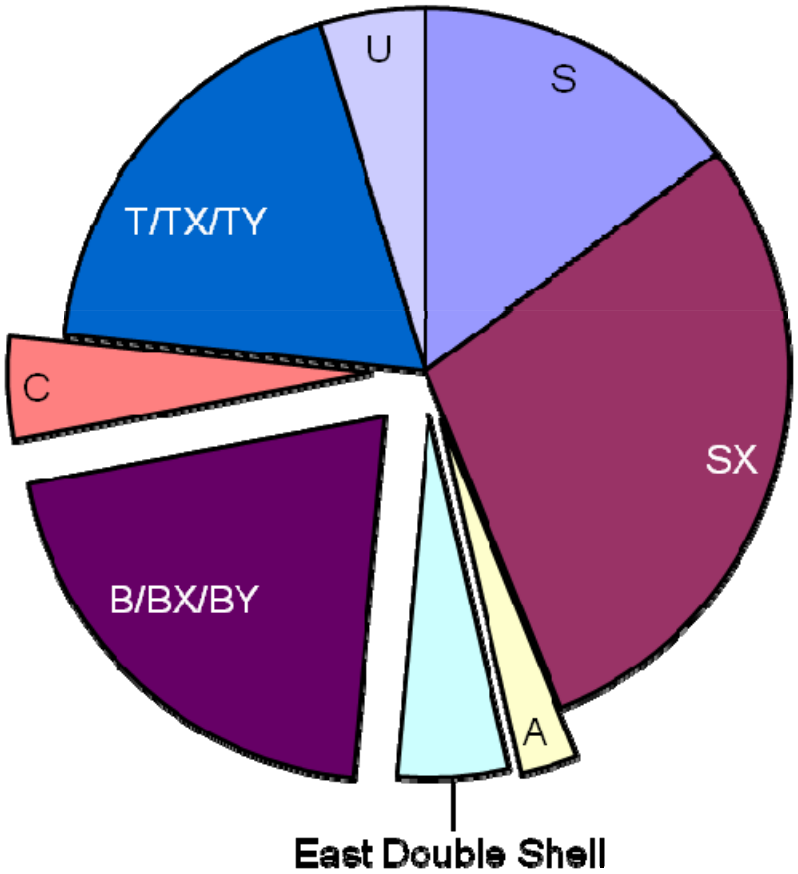
What is Near Tank Cesium Removal (NTCR)

- At tank ion exchange system
- Uses Spherical Resorcinol Formaldehyde (sRF) resin
- Utilized fixed lead lag configuration to reduce # of valves
- Utilized limited acid elution to minimize acid production
- Works very well with low K feeds, such as effluent from CSL

Hanford High Level Waste: S/SX Tanks

Relative Mass of Aluminum in S/SX Tanks



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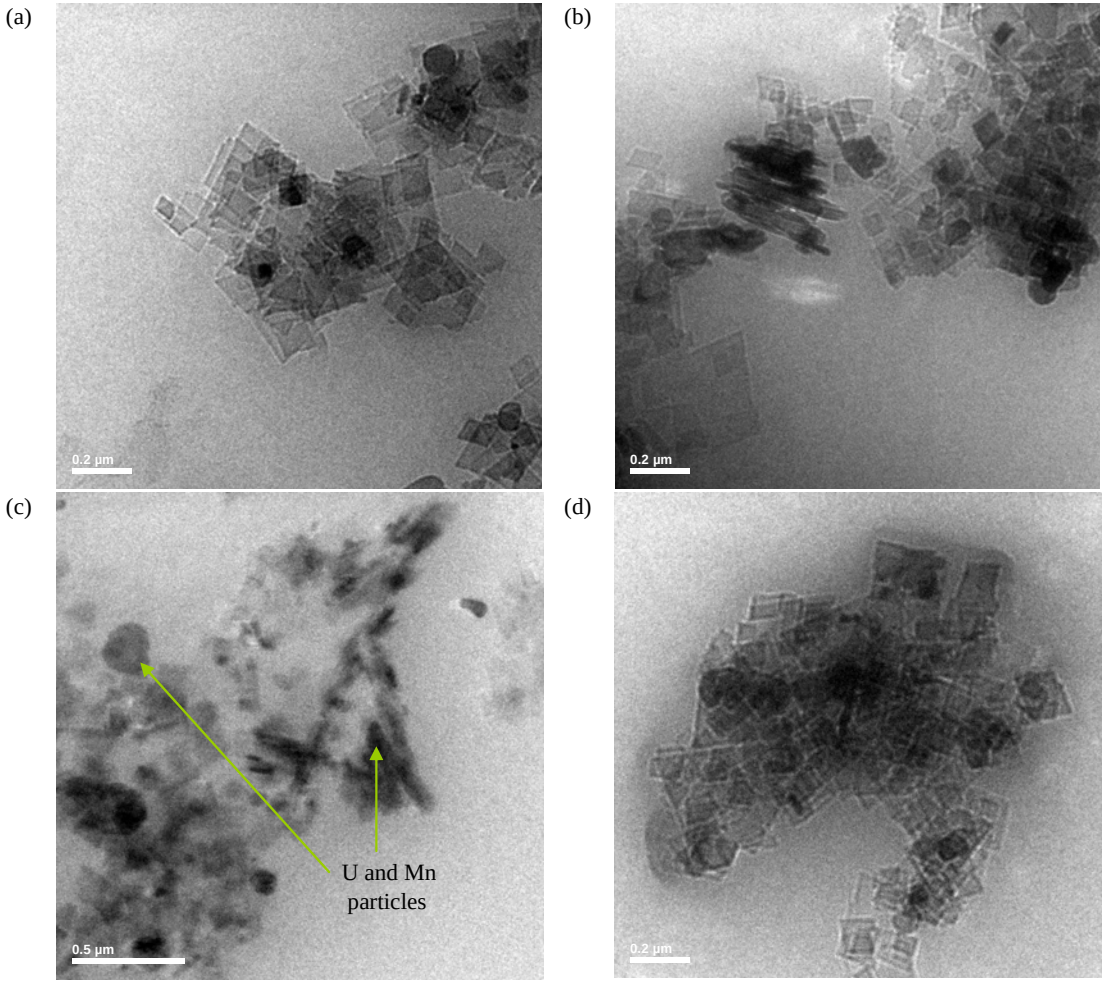
Hanford High Level Waste: S/SX Tanks
TEM Images of Actual Waste Boehmite



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Near Tank Treatment System
Objectives

- Continuous Sludge Leaching
  - Dissolve ~90% of the Al present in the solid phase in the HLW Hanford S/SX waste tanks
  - Separate and concentrate the HLW residual solids from the Low Activity Waste (LAW) leachate
- Near Tank Cesium Removal
  - Decontaminate the leachate to allow contact maintenance
- Ceramatec Ionic Membranes
  - Recover NaOH from the leachate to be re-used in the leaching process (target 10 M NaOH for recycle)

Continuous Sludge Leaching
Full scale equipment description

- 6000 gallon reactor vessel
- ~ 100 sq ft of filter area
  - Single 100 tube bundle
- Processes 200 kg/h of S/SX waste
- Produces 150 kg/h of leached slurry
- Removes 90% of the aluminum
- Achieves 60% reduction in mass of insoluble solids
- Produces 3000 kg/h of leachate
- 100 h reactor residence time

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Continuous Sludge Leaching
Bench Scaling Testing

- Prior boehmite leaching data is exclusively from batch reactors
- Existing model indicates that the presence of aluminate will suppress reaction rate
- Primary objective is to assess whether the existing kinetic model from batch data will adequately express reaction rates for continuous tests

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Continuous Sludge Leaching
Bench Scaling Testing

- 1 L reactor vessel
- Fresh feed added in 10 mL increments
- All flows were by gravity
  - Used balances to control quantity of material delivered and removed
- Tests performed with varying residence times (frequency between time the valves cycled)
- Reactor vessel held at constant temperature

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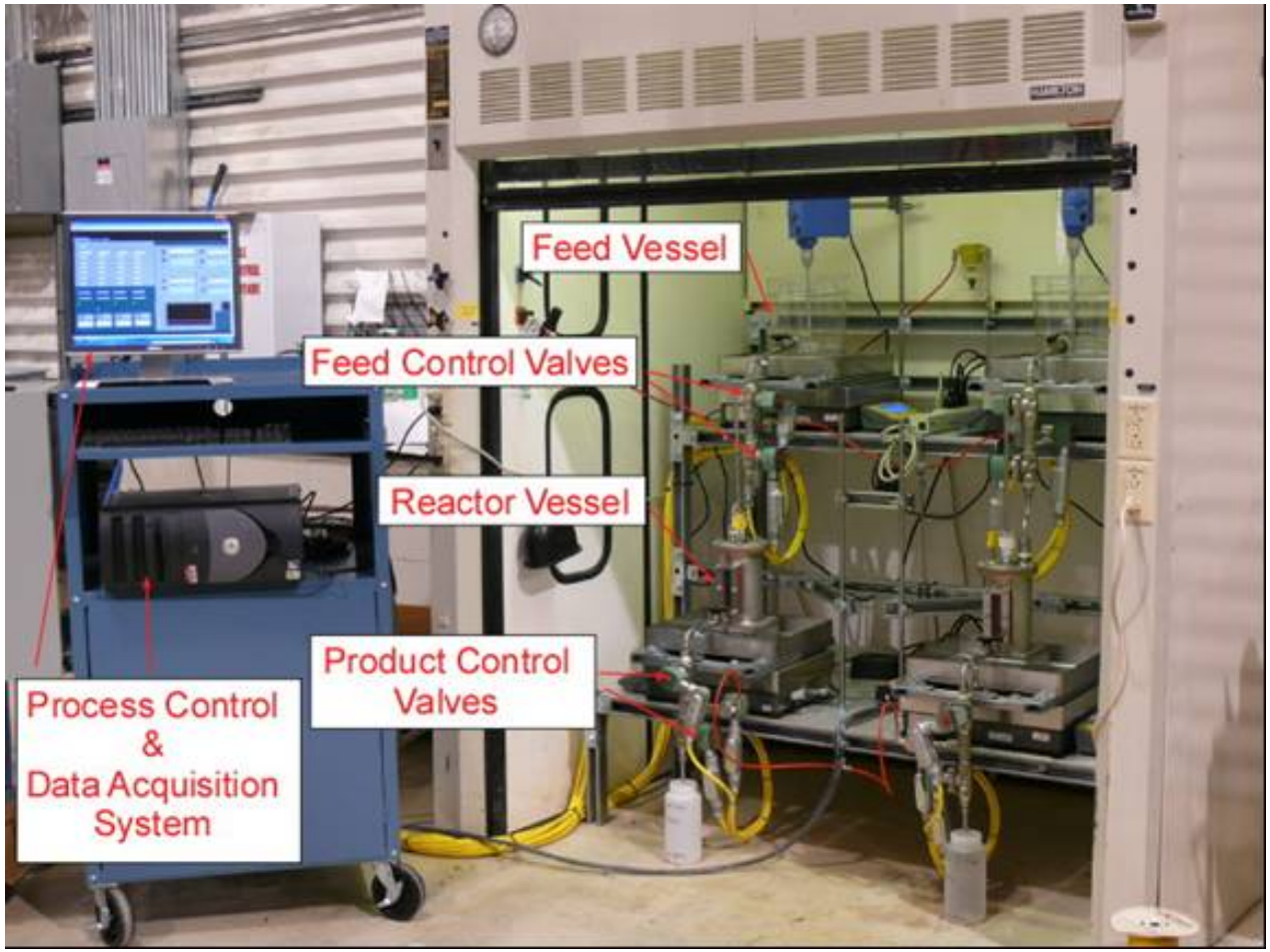
Continuous Sludge Leaching
Bench Scaling Testing



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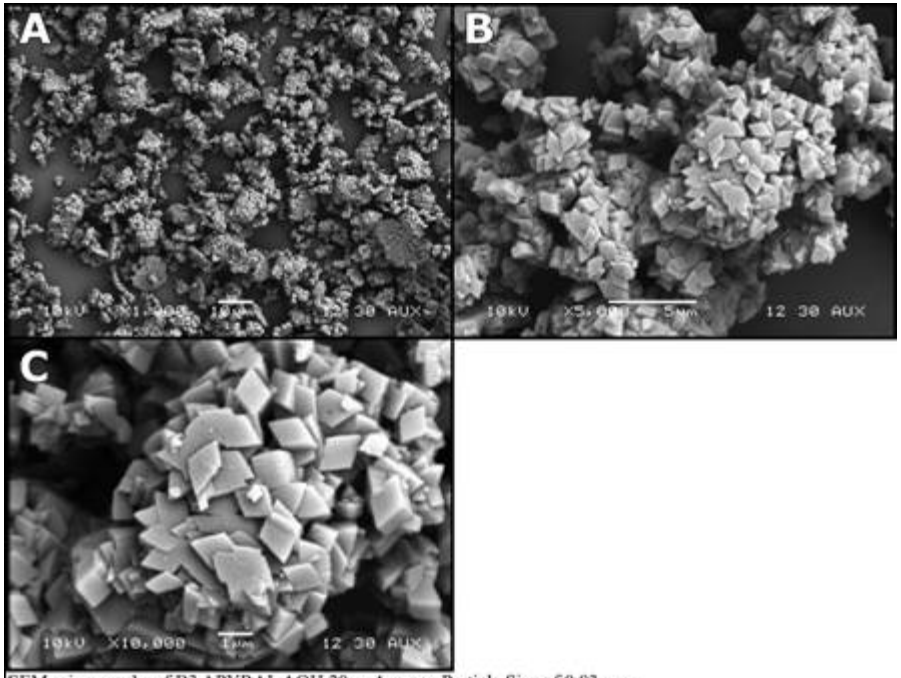
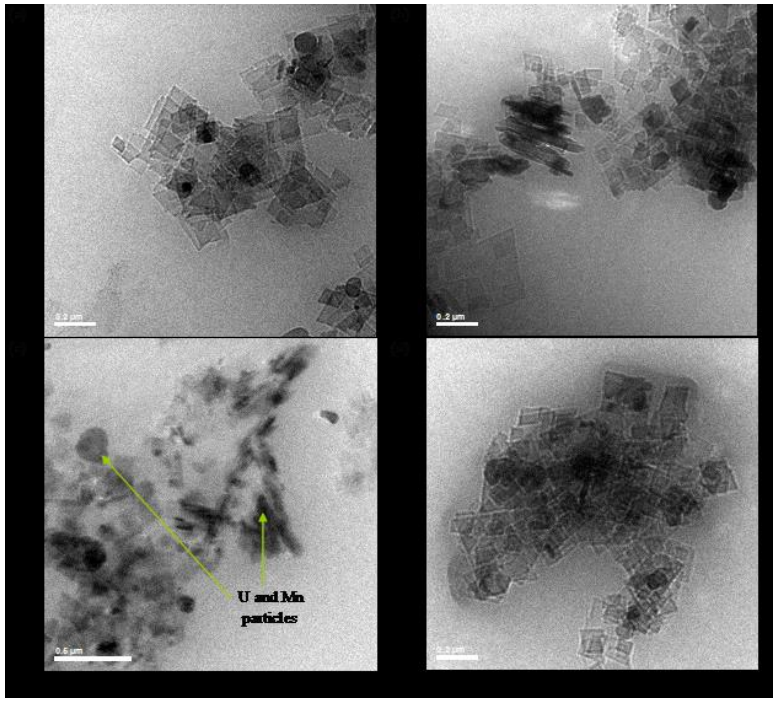
Simulant demonstration: actual waste crystals are 2-3 times smaller than simulant crystals



SEM micrographs of B3 APYRAL AOH 20 . Average Particle Size of 0.83 µm.

Simulant boehmite



Actual waste boehmite

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Test Matrix

Test ID	OH Conc. (M)	Wt% Boehmite	Wt% CrOOH	Residence Time (hr)
KA-1	5	2.53	0.25	100
KA-2	3	1.50	0.15	300
KA-3	3	2.26	0.23	100
KA-4	5	3.79	0.38	300
KA-5	4	2.62	0.26	200
KA-6	4	2.62	0.26	200

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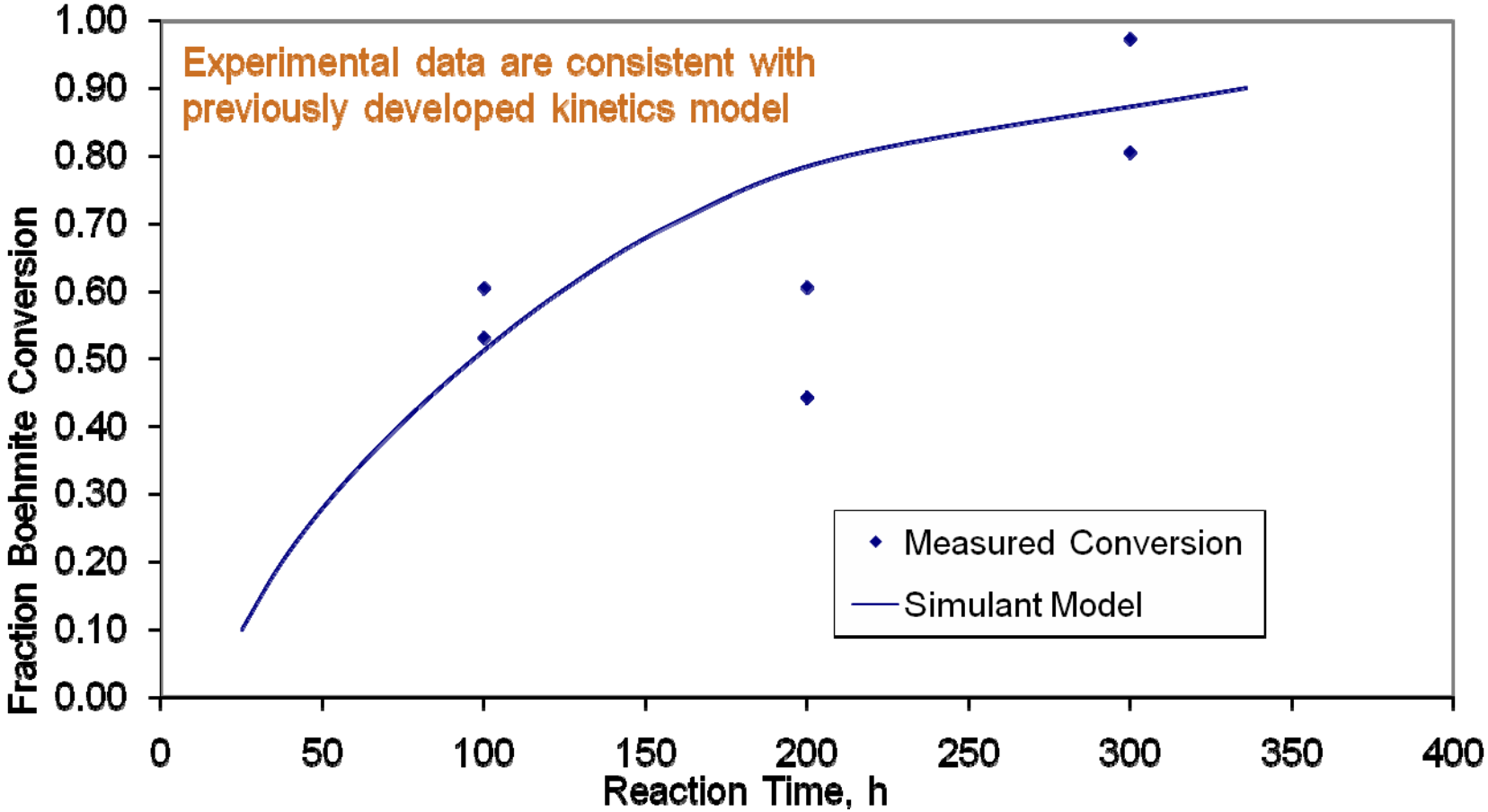
Continuous Sludge Leaching
Bench Scale Testing Conclusions



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Continuous Sludge Leaching
Bench Scale Testing Conclusions

- Data are consistent with the batch leaching model
- A trade-off exists between the quantity of caustic used and the throughput that can be achieved
- Maximum Al throughput will be achieved at 90% dissolution

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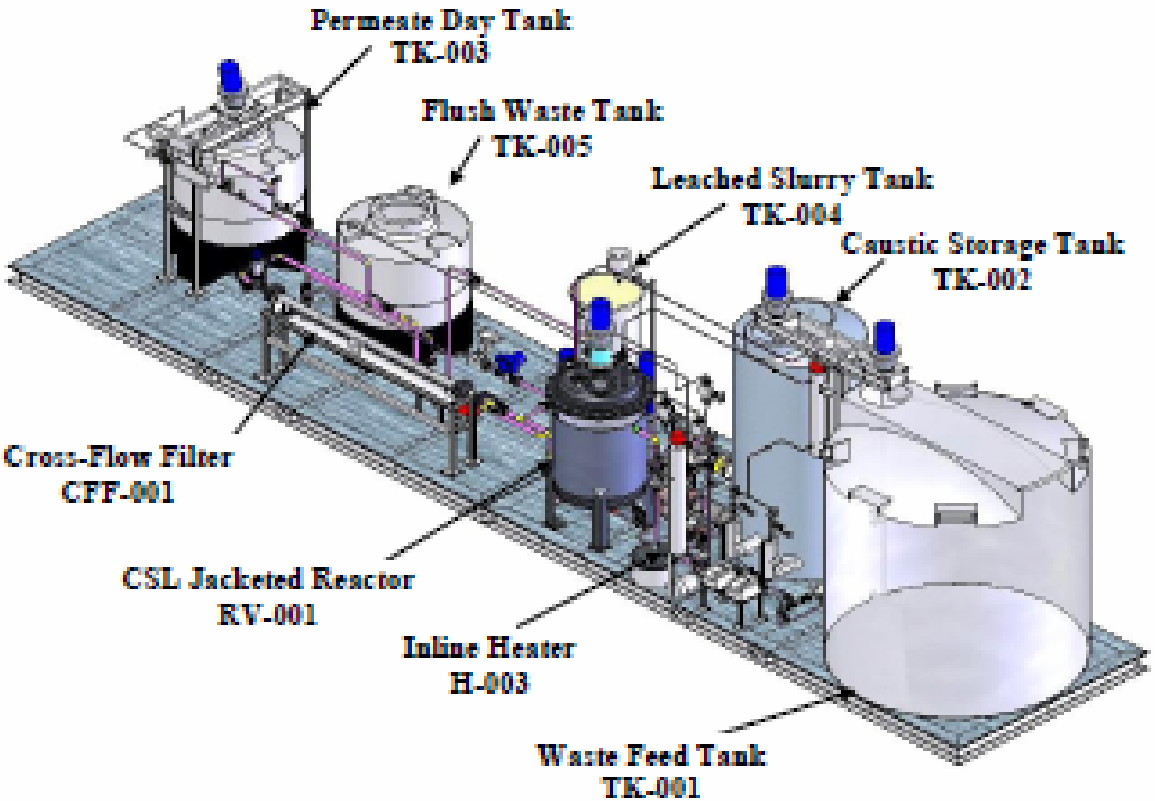
Continuous Sludge Leaching
Pilot Scale Testing



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Continuous Sludge Leaching
Pilot Scale Testing

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Near Tank Cesium Removal
Process Overview

- Batches of 60 m^3 (16 kgal) of filtered leachate (5–7 M Na) accepted into the NTCR feed tanks
- Processed downflow through two beds (lead-lag) of Spherical Resorcinol-Formaldehyde (sRF) Cs IX resin
- Processing ends when Cs breaks through lead column
- Downflow feed displacement with 0.1 M NaOH
- Upflow elution of lead column with 0.5 M HNO_3 at low temperature
  - Higher density eluate below displacer promotes plug flow
  - Upflow keeps downstream piping, valving, etc. “clean”
  - Low temperature extends resin lifetime

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Near Tank Cesium Removal
Process Overview

- Upflow regeneration with high density solution
  - 2 M NaOH, 3 M $NaNO_3$
  - Completely flushes lower density loaded eluate from column
  - Matches density of feed for next load cycle
- Decontaminated LAW feed delivered to WTP LAW melter or supplemental treatment (such as Bulk Vitrification)
- Cesium-rich eluate neutralized with used process solutions, then stored or delivered back to Hanford tank farm

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Near Tank Cesium Removal
Bench Scale Testing Objectives

- Assess impact of proposed process conditions on Cs ion exchange performance
  - Abbreviated LAW displacement
  - Short up flow elution
  - Up flow resin conversion to Na form with high density solution
- Evaluate impact of feed variability on resin performance
- Evaluate low temperature cesium elution
  - Extends resin lifetime

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Near Tank Cesium Removal
Bench Scale Testing Methods

- Small columns (10 mL resin beds) to minimize waste generation; one jacketed for low temperature elution
- Four simulants; three that bracket compositions of the likely first four double shell tank supernates, and one of a dissolved saltcake
  - Target 6 M Na and 5 M Na feed concentrations
  - Bracket Cs and K concentrations expected in tanks
  - Simple compositions, but include components that test for efficiency of feed displacement and resin conversion: $Al(OH)^-_4$, NO_2^-, CO_3^{-2}

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Near Tank Cesium Removal
Bench Scale Testing System

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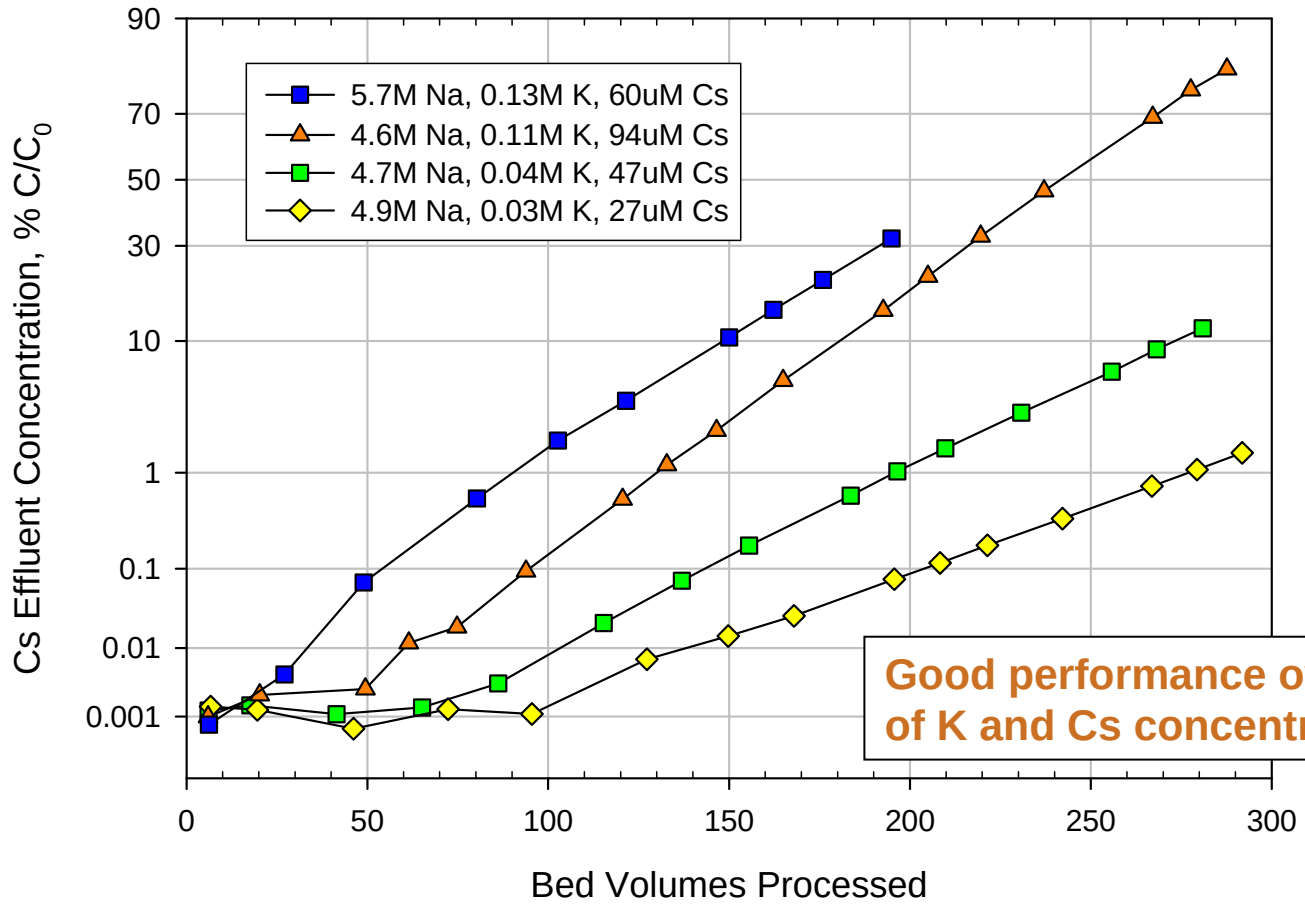
NCTR: Small Column Ion Exchange Tests
Effect of Feed Variability at 3BV/hr



Good performance over a large range of K and Cs concentrations

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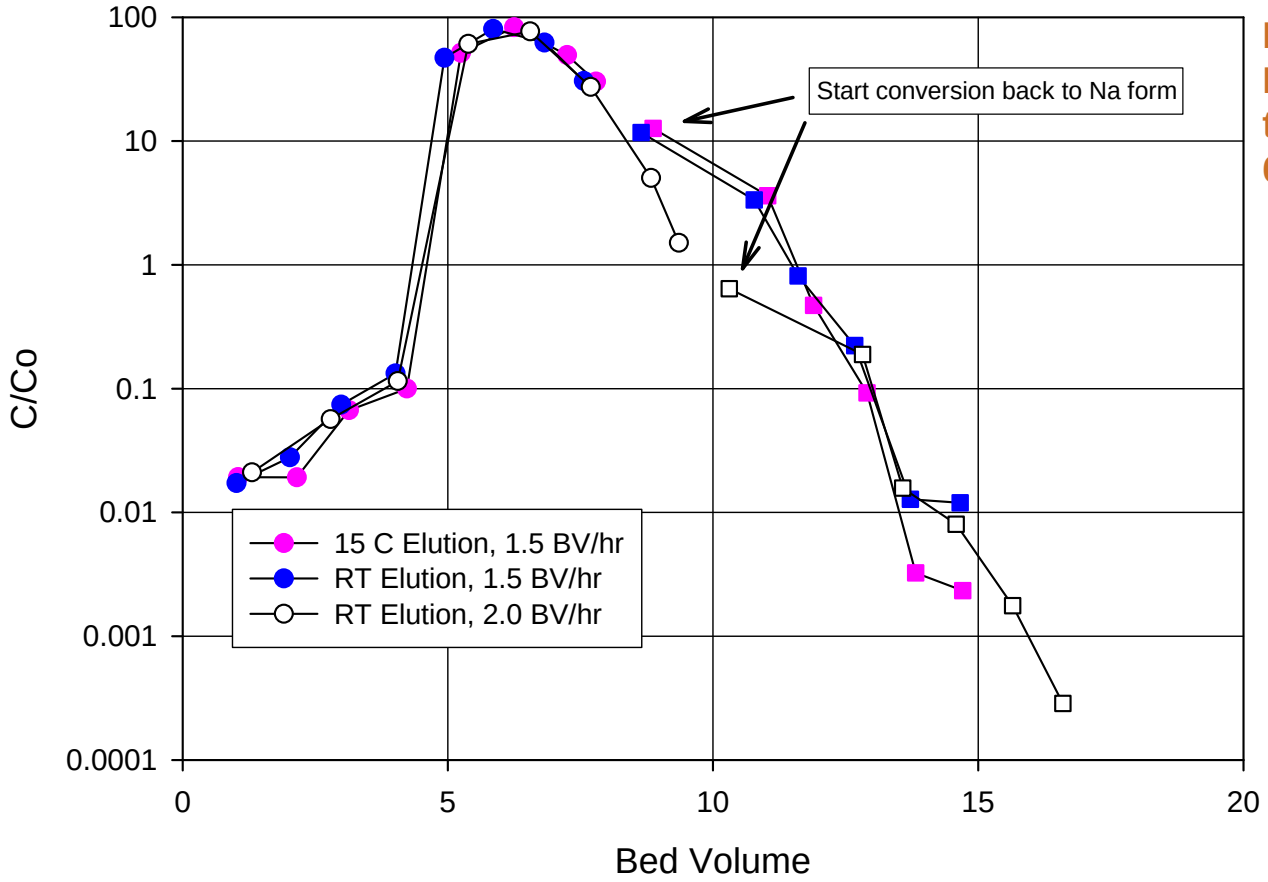
NCTR: Small Column Ion Exchange Tests
Upflow Elution and Na Conversion



Elution: 0.5 M HNO3
Na Conv: 3 BV 1M NaOH then 3 BV 1M NaOH + 6 M NaNO3

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Near Tank Cesium Removal
Bench Scale Testing Conclusions

- Successfully demonstrated abbreviated process conditions
- Assessed impact of feed variability – good performance for all target feeds
- Successfully demonstrated reduced temperature elution
  - Ion exchange dominated by diffusion processes, proportional to temperature
  - Resin degradation rate dominated by chemistry, exponential dependence on temperature

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Near Tank Cesium Removal
Process Comparison

	Reagent Used		Flow Direction		Flow Rate (bed volume/hr)		Volume Processed (bed volume)	
	WTP	NTTS	WTP	NTTS	WTP	NTTS	WTP	NTTS
Loading	Feed	Feed	Down	Down	3	3	(a)	200[(b)]
LAW Displacement	0.1 M NaOH	0.1 M NaOH	Down	Down	2	3	4	4
Elution	0.45 M HNO_3	0.5 M HNO_3	Down (25° C)	Down (10-15° C)	1	1.5	15	7-9
Regeneration	0.25 M NaOH	1) 1 M NaOH 2) 2M NaOH + 3 M $NaNO_3$	Up	Up	6.8	3	6	1) 3 2) 3

(a) To predetermined maximum for breakthrough of the lag column.
(b) Target of nominally 1 percent breakthrough on the lead column.

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NTTS: Technology Readiness Assessment
Previous Development Activities

System	Critical Technology Element	Technology Readiness Level
CSL	Continuous Dissolution	3
CSL	Ultrafiltration	4
CSL	Raman Process Monitoring	3
NTCR	Resin Chemistry	4
NTCR	IX Column Operation	4
Caustic Recycle	Electrochemical Cell	4
Overall		3

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NTTS
Current Development Activities

- Perform pilot scale demonstration testing
  - Demonstrate effective removal of boehmite and cesium
  - Identify and demonstrate optimum process conditions
  - Evaluate operating limits
  - Sufficiently characterize product in support of downstream treatment

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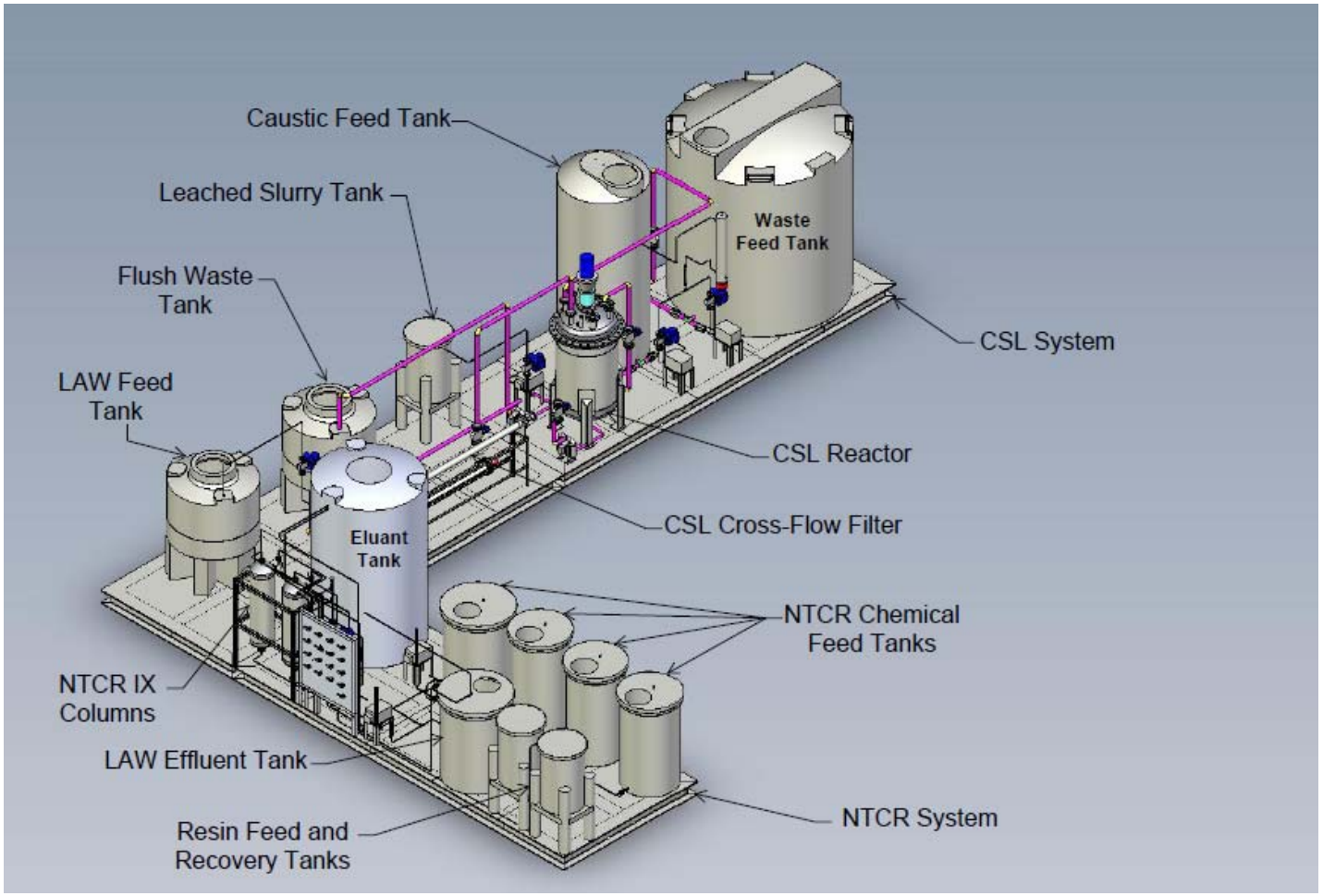
NTTS
Pilot Scale Testing



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NTTS
Future Activities

- Develop conceptual design for full scale system deployment
  - PFD, P&IDs, equipment lay-out, ICDs, etc.
  - Technology Maturation Plan
  - Preliminary safety evaluation and hazard analysis
  - Risk management plan
  - ROM estimate and schedule

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