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TOMORROW'S CERAMIC SYSTEMS

NaSelect® ELECTROLYTIC PROCESS FOR CAUSTIC RECYCLING FROM LOW LEVEL WASTE

Educational Forum on Technologies for Aluminum/Sodium Management

February 8th 2010

Who We Are

CoorsTek
Amazing Solutions.

-100 Year Old Company
- Largest North American Ceramic Component Manufacturer

DEW
ENGINEERING & DEVELOPMENT

- Integrated Composite Armor Solutions

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- Advanced Materials and Electrochemical Technologies

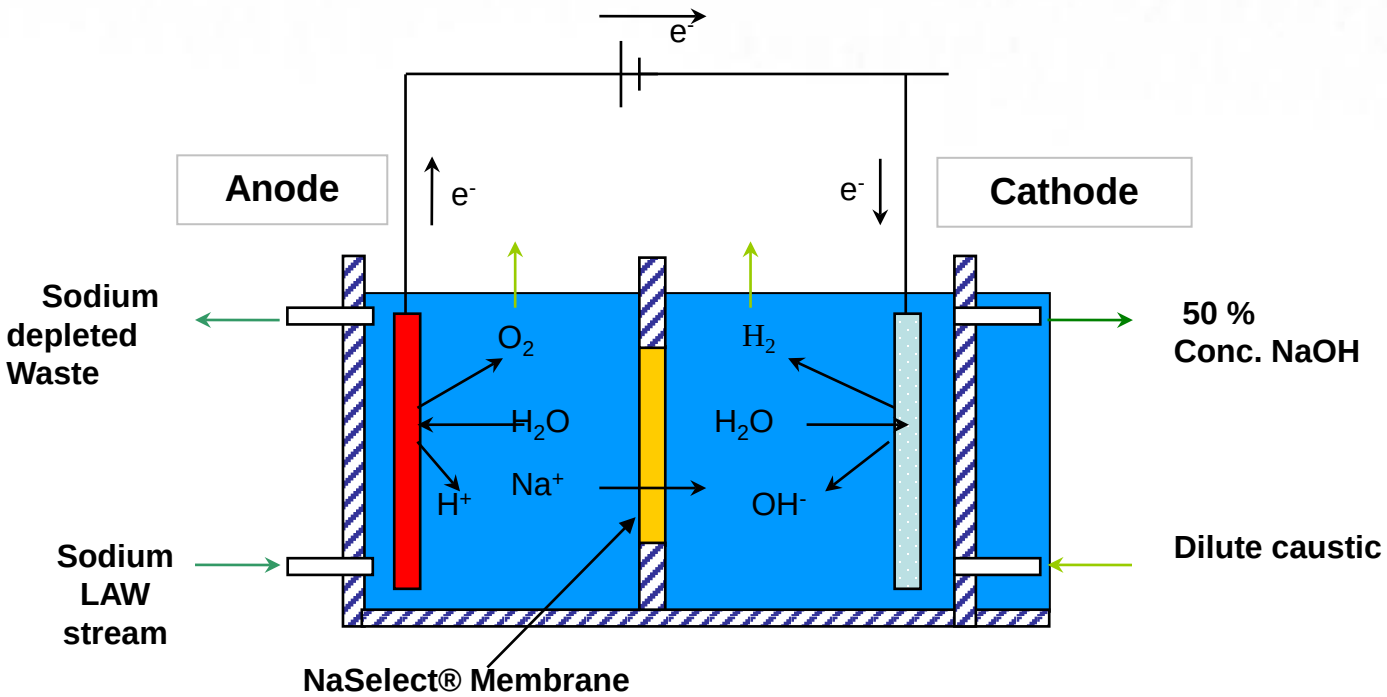
CoorsTek
ARMOR SOLUTIONS

- Armor Components

C5 medicalwerks

- Implantable Ceramic Components and Assemblies

Principle of Operation: Electrolytic NaSelect® Ceramic membrane cell



NaSelect® Membrane

Sodium-Super Ionic- Solid- Conductors

Electrode Reactions:

Anode: $2H_2O = O_2 + 4H^+ + 4e^-$

Cathode: $4H_2O + 4e^- = 2H_2 + 4OH^-$

Overall: $2H_2O = 2H_2 + O_2$

Technology Progression Chart

1996-1997/2004-2006 | **2007** | **2008** | **Feb 2010**

I

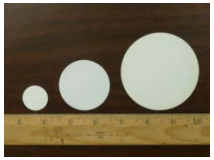
- Planar Design to recycle sodium
- Low energy consuming membrane and Process Development

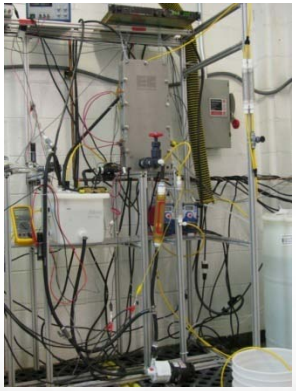
III

- TRL Review
- Produce 50 wt % caustic from AP104 Simulant
- Testing in Actual Waste -4 Independent tests to date
- Caustic recycling economics For 32,000 tons system
- Technology Review by an Independent DOE team

IV

- Statistical performance > 25,000 hours of combined testing
- Design move to Tubular Configuration
- Caustic Recycling from AP104-CSL-PEP-Group 5-NTCR simulants
- System Reliability: Gelling conditions, Dynamic pressure Testing. Production Systems





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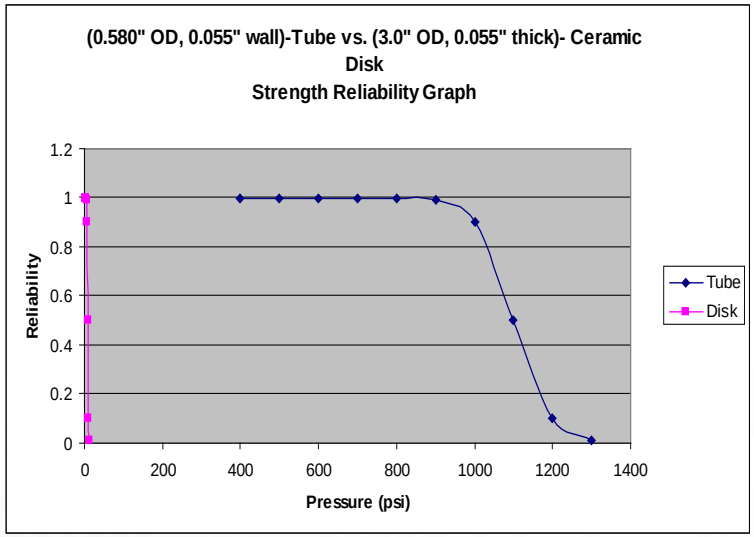
Why Ceramic Membranes

- **Solid and Dense Ceramic membrane**
- **Crystal-Structure transports sodium by migratory process through lattice vacancies under influence of electric field**
- **Selectively transports sodium ions over other ions present is waste streams**
- **Unlike polymer membranes does not foul in presence of solids or complex elements**
- **Electrochemical efficiency greater than 95%**
- **Membranes are chemically stable to corrosive chemicals and operates in a wide pH range**
- **Highly stable to radioactive environment**

Device Design: Shift in Focus from Planar to Tubular Cell Configuration

- Recommendation from DOE Independent team to handle flow in Planar Design
- Tubular membrane allows self cleansing, operation under higher pressure drop conditions, lower number of seals, smaller footprint

Tube: 8 inch tall-0.90 inch diameter



- *Weibull reliability: NaSelect® tubular membrane withstands >400 psi pressure differential*

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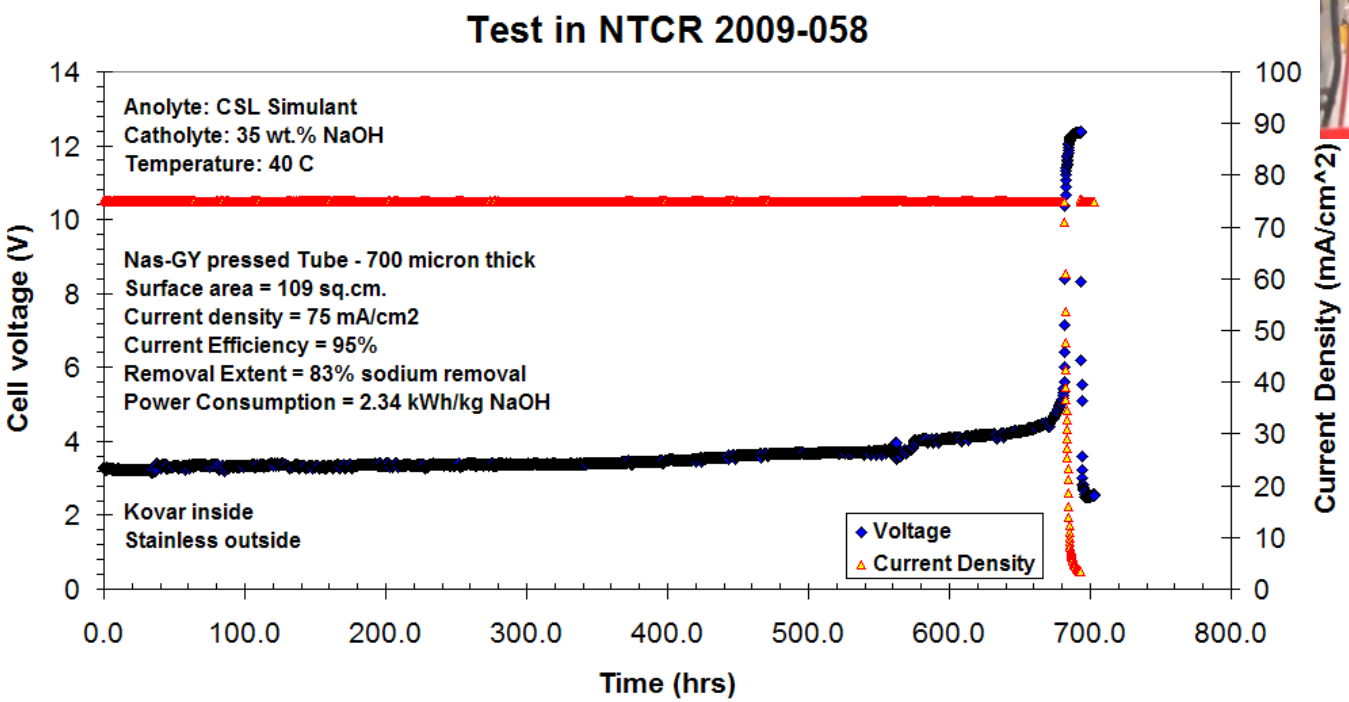
Testing Waste Simulants from with Tubular Cells

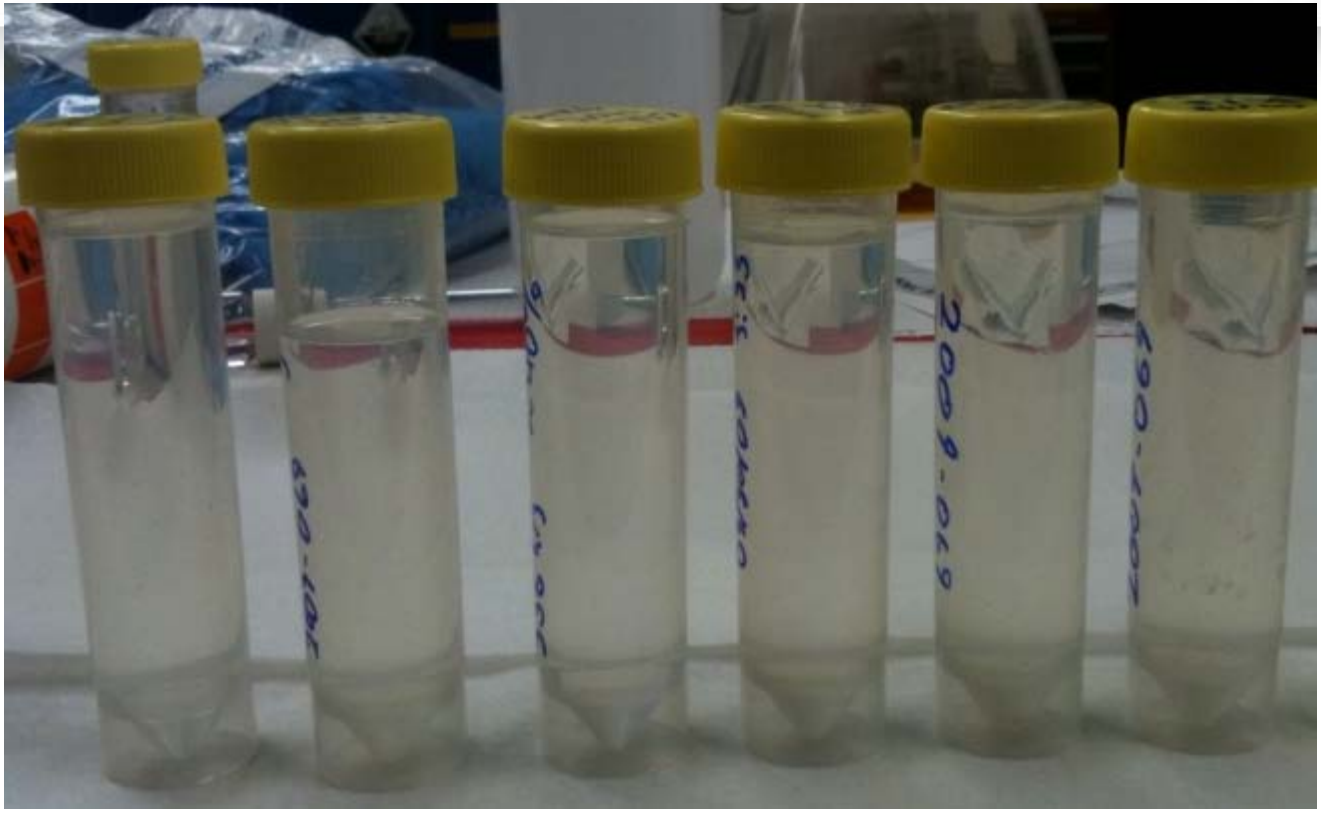
Composition	Group 5	PEP	CSL/NTCR
Na (M)	4.42	7.39	5.01
Al (M)	0.26	0.75	0.25
Starting Na/Al	16.89	9.85	20
Na/Al Molar Ration when alumina precipitates	TBD	3.44	4
Percentage of sodium removed from simulant by NaSelect® cell at 40°C before precipitation	45 %	65%	80%

NTCR Simulant Testing



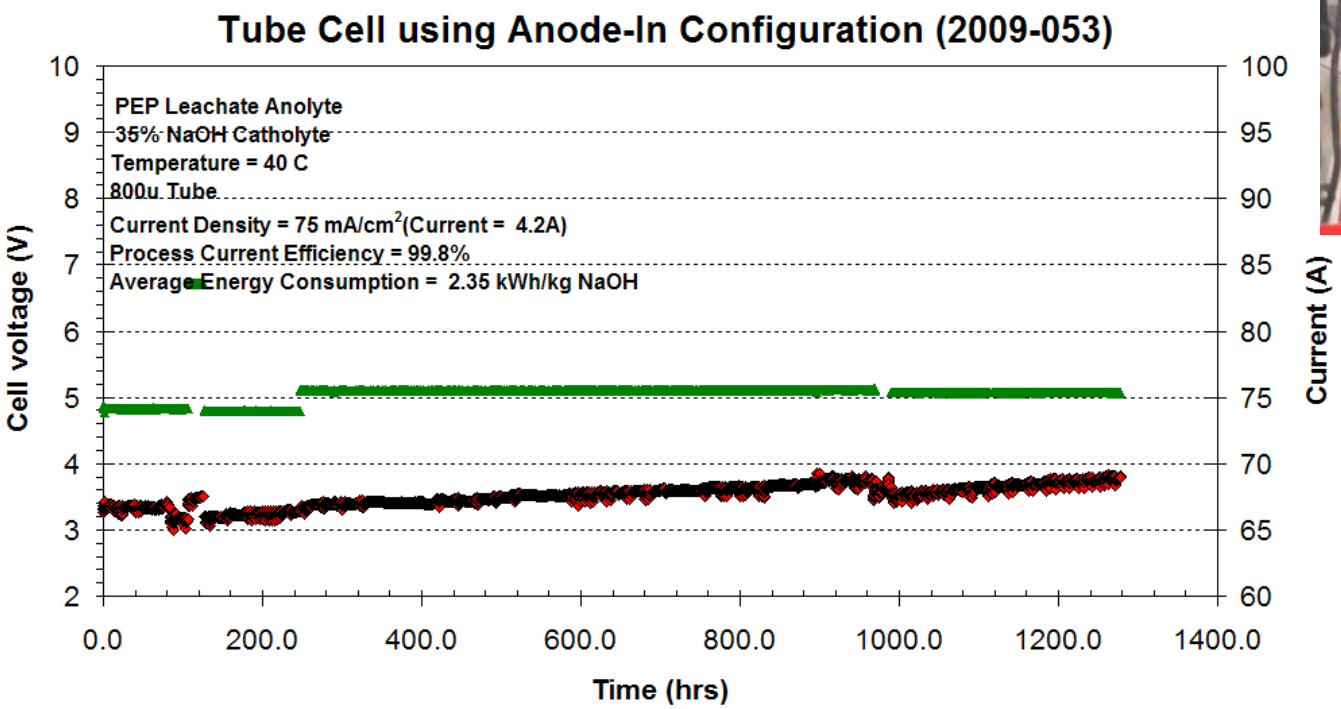
- 83% sodium removed from CSL simulant
- Batch mode operation of cell
- Power consumption (2.34 kWh/kg of NaOH produced)
- Cell operated in the alumina precipitated region

Characterization of simulant after sodium separation



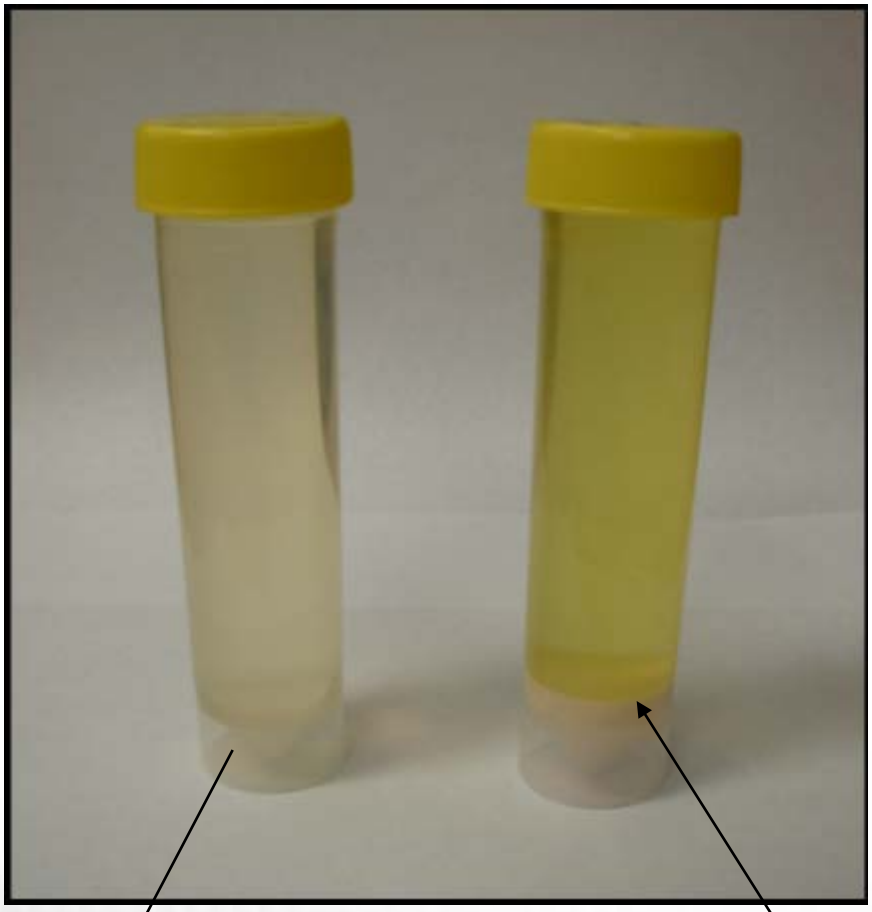
- NTCR Samples after 10, 30, 40, 50, 65, and 80% sodium removal from left to right
- Alumina precipitation observed in the 80% sodium removed sample

PEP Simulant Testing



- 65% sodium was removed from PEP leachate
- Batch mode operation of cell
- Power consumption-2.35 kWh/kg of NaOH produced

PEP Leachate Characterization: Before and After Sodium Removal



As received PEP

Alumina Precipitate

- Alumina precipitation appears after 65 % of sodium is separated during 45°C cell operation
- Alumina precipitation occurs after 68% of sodium is removed at 60°C cell operation
- XRD analysis identified the phases as Bayerite $Al(OH)_3$ and Gibbsite -$Al(OH)_3$
- A Rietveld refinement using crystal structure information from the AMCSD estimated the Bayerite and Gibbsite amount at 61.2% and 38.8% respectively.

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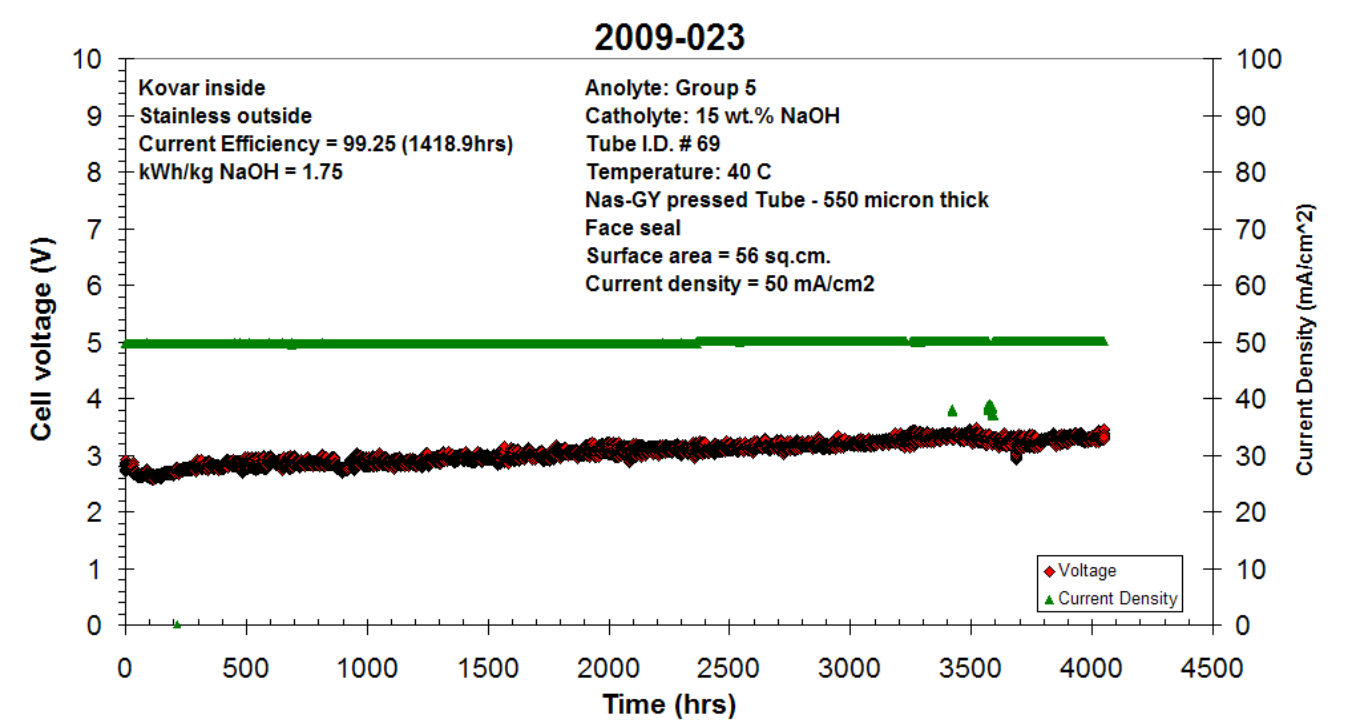
Group 5 Simulant Testing



- Long term test ongoing past 5 months: Continuous mode operation to recycle sodium from simulant chemistry
- Power consumption-1.75 kWh/kg of NaOH produced

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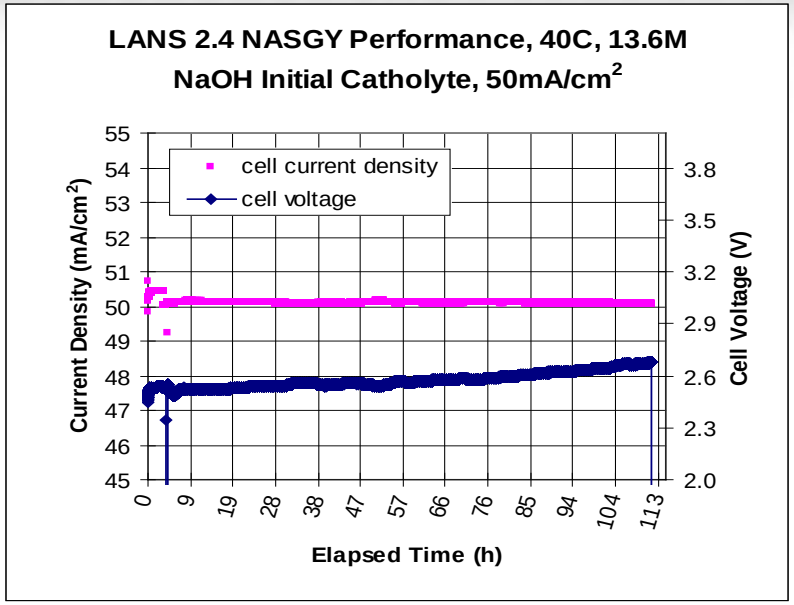
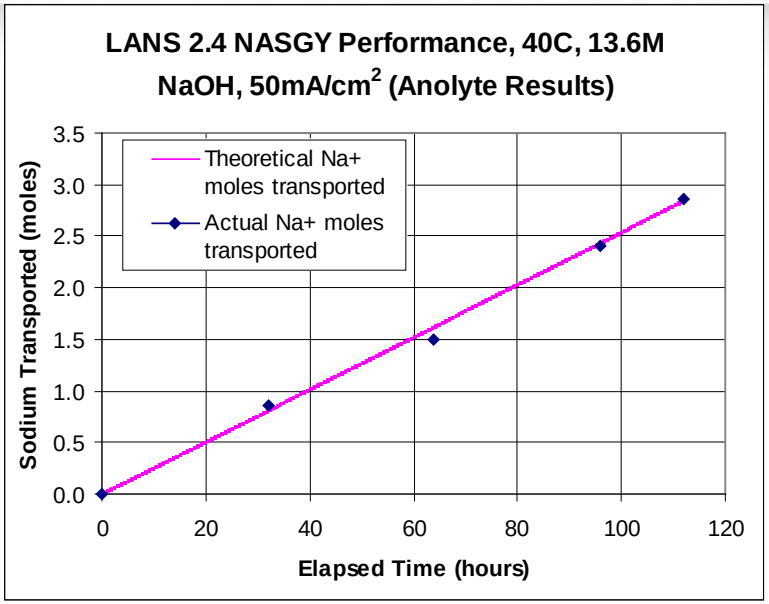
Testing Results in Actual Waste at PNNL





- Good agreement between theoretical Na transport based on applied current
- Na transport based on OH^- titration results.
- Average Na transfer rate of 10.2 kg/day/m^2
- *99% sodium transport efficiency*
- Cs-137 Decontamination Factor = 5585- GEA analysis)
- No other radionuclides were transported and measured in the catholyte solution above detection limits

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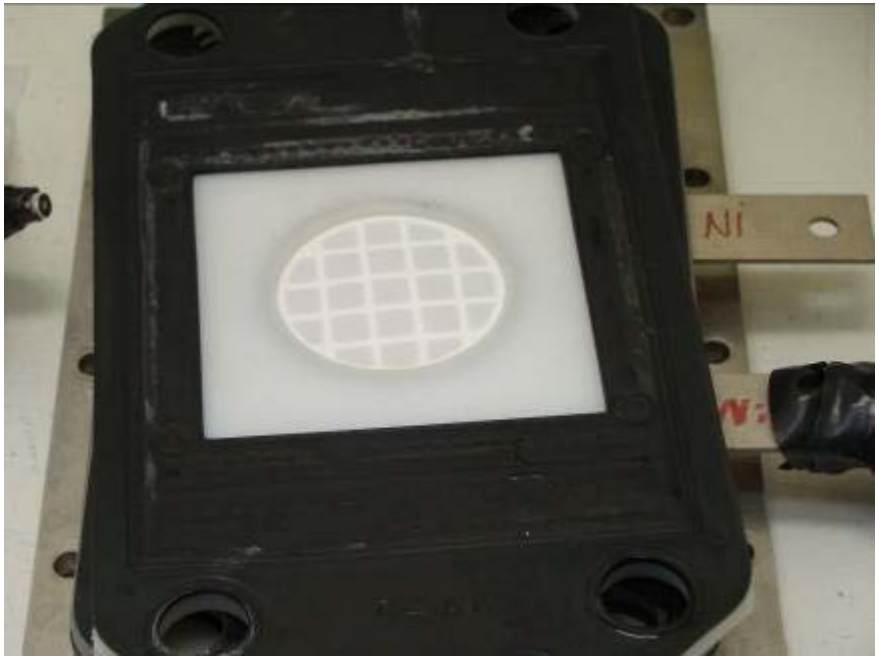
Post Experimental Investigation of Cell

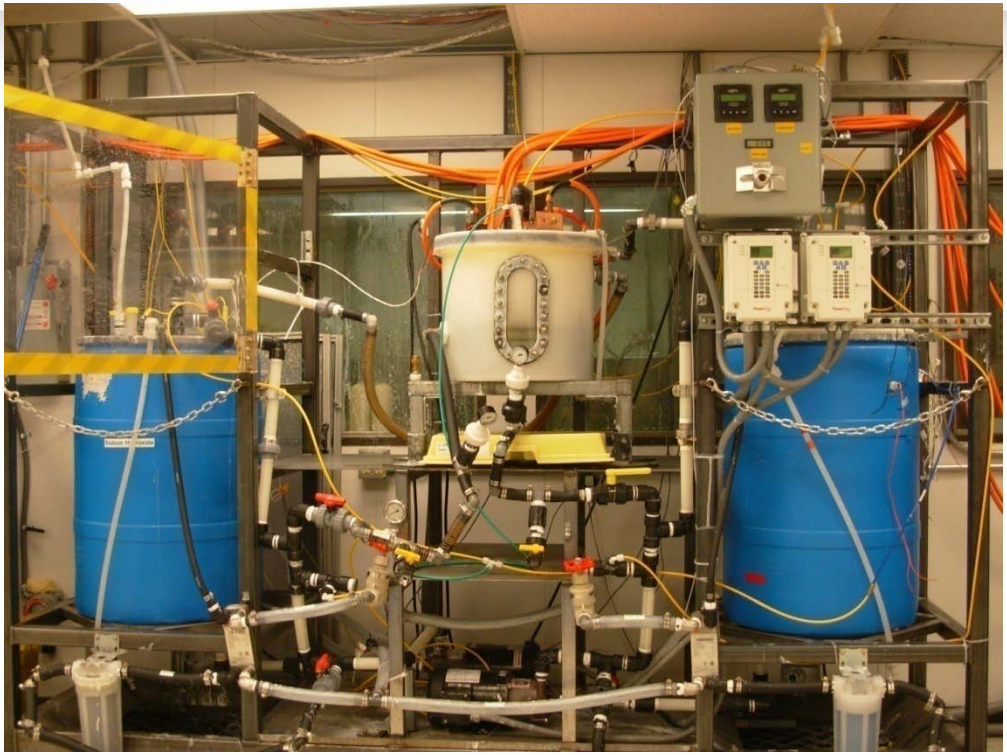


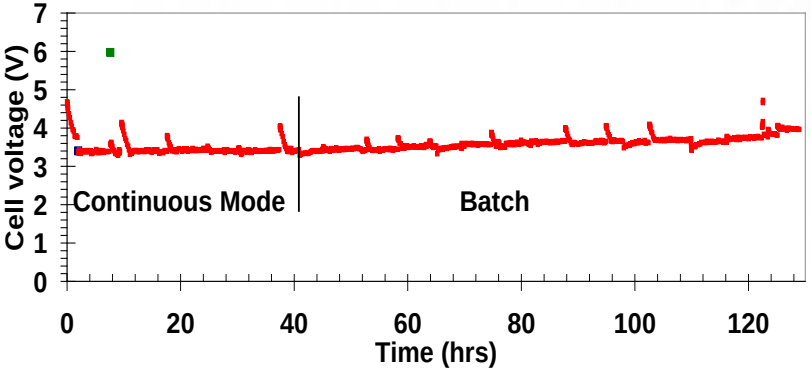
- Post experimental visual inspection of the membrane *shows no membrane degradation*

Technology Demonstration Phase - 2009 Activities

- Ceramic tubular configuration device scale up
  - smaller foot print, minimize seal area- reliability
- Process development to meet site needs
  - Caustic recycling economics to recycle sodium for near term use
  - Based of sodium flow sheet requirements for CSL and NTCR processes
  - Impact on stream stability from maximum sodium separation
- Engineering Scale Up- Technology Demonstration unit (TDU)
  - Demonstrate maturity of process

Multi-Tubular Prototype-Design to be scaled to TDU size

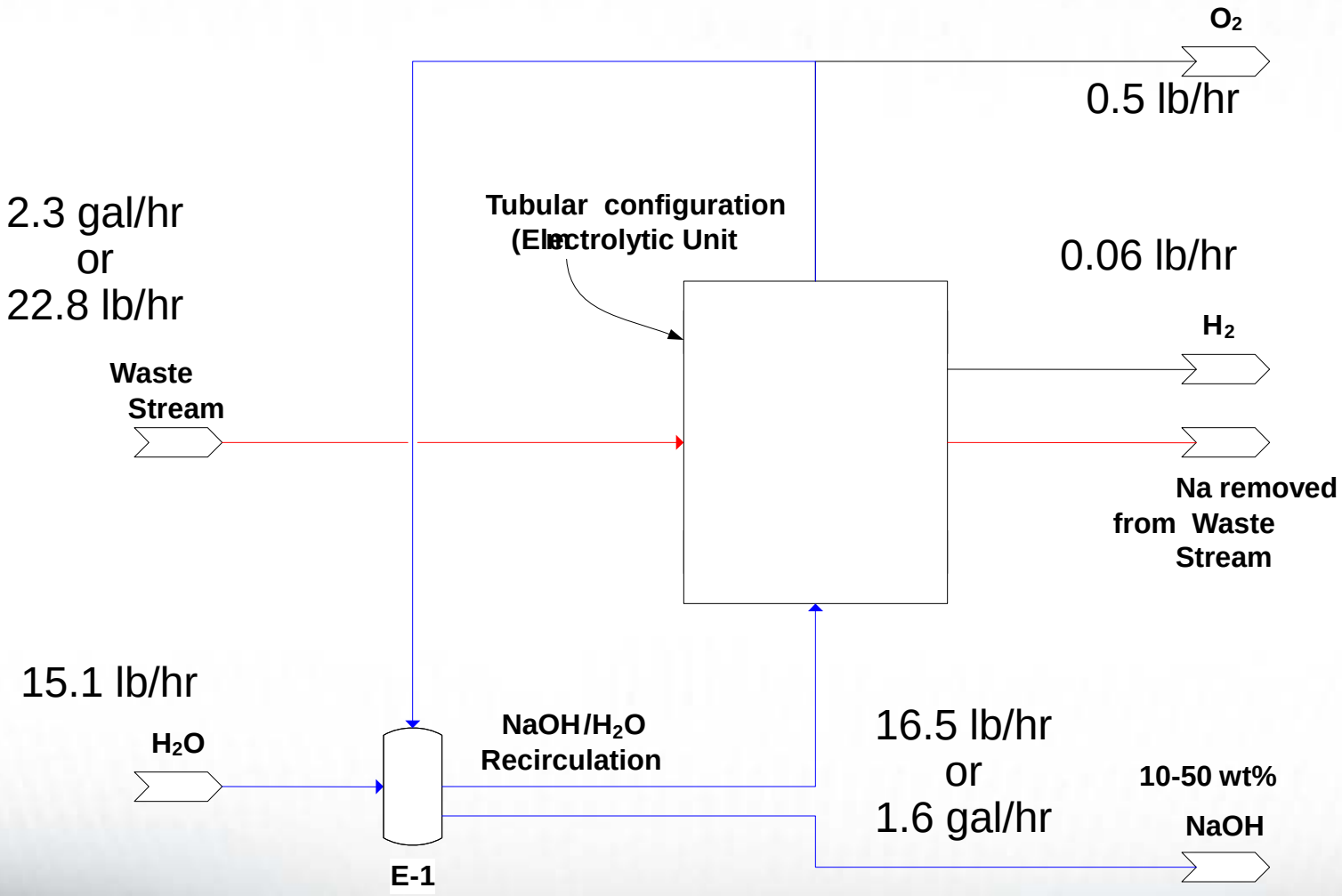




22 NaSelect® tubes (0.3 m^2 based unit)

- Pressure drop across cell (400 psi)
- Self cleansing to eliminate any solids and precipitation
- Process Feed: 1 gallon per minute
- Performs identical to a single membrane cell in batch or continuous mode

Tubular: Technology Demonstration and Maturity Unit (TDU)- Continuous Process - February 2010



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Sodium Methoxide Production System

- Scaled up modular sized system for producing Sodium Methoxide in methanol (SMO) for Biodiesel production
  - 1500 lbs/day on a 100% basis of SMO
- Scalable Modular Technology: Process controls and monitors

Liquid-gas separation, gas handling system design, safety and reliability for unit operation

Summary

- > 25,000 hours of cell testing conducted to recycle sodium and validate the cell design and establish process reliability
- Four successful tests conducted for sodium recycling from actual wastes at PNNL and SRS
  - Gamma radiation exposure of cell components completed
- Tubular ceramic configuration offers advantages over planar
- 65%-75%-80% removal of sodium from CSL-PEP and NTCR waste simulants demonstrated before precipitation of Alumina occurs
- Multi-tube cell module design successfully demonstrated
- TDU- multi-tube cell modular unit being tested: February 2009 operation
- Process is *scalable* as demonstrated by commercial application
- CoorsTek onboard for large scale NaSelect ® manufacturing
- Ready for next Pilot Phase Integrated demonstration

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