EDR 201
Electrodialysis Reversal II

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Outline

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2. Type of Membranes
3. EDR Stack Components
4. EDR System Components
5. Leak Test
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7. Desalting Run
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Advanced EDR Operating Principle

- Equal charge of anions and cations are transferred from the product stream to the concentrate stream.

- Electrolyte steams are next to the electrodes to carry current across the stack and maintain charge balance in each compartment.

- Electrolyte is usually Na₂SO₄ solution.
Advanced EDR Operating Principle

- A purge is done when changing polarity. During a purge, water from both product and concentrate compartments are sent to the concentrate stream to prevent contamination.

- Reversal events can be triggered by a set timer or when stack resistance reaches a set point.
Types of Membranes

Electrodialysis reversal systems use electrically charged ion exchange membranes. These membranes have fixed ions on the pore walls that bind to oppositely charged ions in the surrounding fluid while letting similarly charged ions permeate through.

Anion Exchange Membrane (AEM)

Cation Exchange Membrane (CEM)
# Types of membranes

Saltworks offers six types of membranes under the IonFlux name:

<table>
<thead>
<tr>
<th>Type</th>
<th>AEM</th>
<th>CEM</th>
<th>mAEM</th>
<th>mCEM</th>
<th>pAEM</th>
<th>pCEM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type</strong></td>
<td>Anion permselective</td>
<td>Cation permselective</td>
<td>Monovalent anion permselective</td>
<td>Monovalent cation permselective</td>
<td>Proton blocking anion permselective</td>
<td>Proton permselective</td>
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<tr>
<td><strong>Ion Transport</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cl⁻</td>
<td>High</td>
<td>-</td>
<td>High</td>
<td>-</td>
<td>High</td>
<td>-</td>
</tr>
<tr>
<td>SO₄²⁻</td>
<td>Very High</td>
<td>-</td>
<td>Low</td>
<td>-</td>
<td>High</td>
<td>-</td>
</tr>
<tr>
<td>NO₃⁻</td>
<td>High</td>
<td>-</td>
<td>Very High</td>
<td>-</td>
<td>High</td>
<td>-</td>
</tr>
<tr>
<td>Na⁺</td>
<td>Medium</td>
<td>High</td>
<td>Medium</td>
<td>High</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Ca²⁺</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Very Low</td>
</tr>
<tr>
<td>H⁺</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Very Low</td>
</tr>
<tr>
<td><strong>Max. Op. Temp</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>60 °C</td>
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<tr>
<td><strong>pH Stability</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0 - 12</td>
</tr>
<tr>
<td><strong>Applications</strong></td>
<td>Electrodialysis (EDR), Electrodeionization (EDI), Capacitive deionization (CDI)</td>
<td>Selective ion separation</td>
<td>Acid recovery, Acid and base generation</td>
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<td></td>
</tr>
</tbody>
</table>
EDR Stack Components

Separation of ions occurs inside the EDR stack.

3 main components:
• **Electrodes** at the ends
• Alternating **membranes** and **spacers** in between
  ▪ Anion Exchange Membrane
  ▪ Concentrate spacer
  ▪ Cation Exchange Membrane
  ▪ Product spacer

Saltworks’ micro stack for bench testing

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EDR Stack Components

Electrodes:
• Constructed of inert metals, usually platinum coated
• Conducts direct current into the stack
• Polarity can be periodically reversed

Inside surface of electrode

Saltworks™

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EDR Stack Components

Spacers:
- Direct product and concentrate streams into separate single manifolds
- Increase turbulence to promote mixing of the water and break up particles on the membrane surfaces
Membranes:
• Selectively permeate anions or cations depending on membrane type
• Low electrical resistance, insoluble, impermeable to water under pressure
• Must remain moist at all times
EDR System Components

Simplified representation of a bench scale EDR system. Some instrumentations and components have been removed.

Saltworks’ bench scale EDR system has been used to successfully treat mine water, recover acids, and desalinate wastewater.
EDR System Components

Tanks:
- Holding vessel for each fluid
- Saltworks’ proprietary Rinse (R) stream acts as a hardness blocker
EDR System Components

Pumps:
- Circulate each fluid through the stack and back to the tank or out of the plant
EDR System Components

Cartridge Filters:
- Installed downstream of the pumps to filter out particulates and sediments
EDR System Components

Reversal Valves:
• Mechanically reverse the Product (P) and Concentrate (C) compartments within the stack
EDR System Components

Power Supply:
- Creates electrode potential
- Polarity can be reversed
Leak Test

**Purpose:** to detect and minimize leaks between product (P) and concentrate (C) streams. Performed with ~20mS/cm NaCl solution in all tanks after stack assembly.

**General Procedure:**
1. Operate the stack without power supply for a set time
2. Measure P and C tank level changes, if level changes are greater than specified threshold, re-torque the stack according to manufacturer's setting
3. Repeat steps 1 and 2 until P and C tank level changes are within the specified threshold
4. Stack passes leak test and ready for operation
Desalting Run

**Purpose:** to confirm stack performance. Performed with ~20mS/cm in P and C tanks, 0.5 M Na$_2$SO$_4$ electrolyte in E tank, and 0.5 M NaCl rinse in R tank after leak test.

**General Procedure:**
1. Operate the stack with manufacturer specified power supply setting
2. Continue desalting run until P stream reaches 3-5 mS/cm
Current Limit Test

Purpose: to determine operating current. Performed with feed water to be treated in P and C tanks, 0.5 M Na₂SO₄ electrolyte in E tank, and 0.5 M NaCl rinse in R tank after the desalting run.

General Procedure:
1. Operate the stack with power supply settings of voltage at 1V and current at 2A
2. Record current after it stabilizes then increase voltage by 1V. Repeat until specified max voltage is reached
3. Plot voltage vs. current. Find at what voltage current begins to plateau (current limit)
4. Set operating current as 80% of current limit
Hybrid Systems

- Remove hardness from reverse osmosis feed water
- Eliminate chemical costs and safety risks associated with chemical softening
- Extremely high recoveries
- Reduce reject volume and disposal

Saltworks’ EDR-RO hybrid system
Advanced EDR Applications

Mining
- Milling waters
- Mine runoffs
- Acid rock drainage
- Process waters
- Selective recovery

Acid & Base Recovery
- Ion exchange resin regeneration
- Aluminum anodizing
- Acid etching
- Metal pickling

Electrodialysis Reversal

Brine Management
- Inland brackish water
- Concentrate brine
- Water softener

Agriculture
- Phosphogypsum wastewaters
- Agriculture wastewaters

Food & Beverage
- Wine tartaric stabilization
- Water recovery, recycling and reuse
### Case Studies

<table>
<thead>
<tr>
<th>Product</th>
<th>Feed Source</th>
<th>Result</th>
<th>Applications</th>
</tr>
</thead>
</table>
| **ElectroChem Acid Recycle System (pAEM/pCEM)** | Representative ion-exchange regeneration wastewater | • 91% acid recovery  
• Acidic wastewater de-acidified  
• Acid transferred to freshwater (pH 6.5 acidified to pH 0.5) | • Aluminum anodizing, etching, brightening  
• Battery acid and electronics recycling  
• Steel pickling; mineral extraction  
• Ion-exchange resin regeneration |
| **ElectroChem Produced Water Desalter (AEM/CEM)** | High salinity EOR produced water | • 100% recovery  
• 80% total dissolved solids removed | • Water flood enhanced oil recovery water reuse  
• Polymer recycling and reuse  
• Produced water desalination |
| **ElectroChem Salt Splitter (mAEM/mCEM)** | Highly scaling brackish water | • 93% recovery  
• 67% reduction in waste brine volume | • Wastewater treatment  
• Reverse Osmosis hybrids  
• Water softening  
• Selective recoveries and separations |

All case studies are available at [http://www.saltworkstech.com/case-studies/](http://www.saltworkstech.com/case-studies/)