Ultra-Pure Water Transition

Replacing Mixed Ion Exchange Beds with Continuous Electro-Deionization

David Starman, MSCE
Regional Operations Manager - USVI
Seven Seas Water Corporation

Introduction

OUTLINE OF PRESENTATION

- Introduction
    - Outline
    - Intro to David Starman
- Discussion of Ultra –Pure Water Technologies
    - Ultra-Pure Water – Uses and Requirements
    - Mixed Bed Deionization
    - Continuous Electro Deionization
- Comparison of Technologies
    - Typical Advantages/ Disadvantages of Each Technology
- Case Study – Seven Seas Water UPW Installations in the USVI
    - System Designs
    - System Operational Data
    - System O&M
- CEDI in the Caribbean
    - Review of applicability of CEDI with challenges of Caribbean operations
- Questions and Discussion

About Me!

David Starman, MSCE

- Born and Raised in SW Florida on the Gulf Coast
- Bachelors degree in Biology at the University of North Carolina
- Worked in Environmental Remediation industry – Design, install, operation of remediation systems for contaminated soil and groundwater. Typical source of contamination was underground gasoline and diesel tanks at corner gas stations.
- Returned to University of South Florida and studied Civil Engineering, focused on Water and Wastewater treatment.
- Studied membrane processes, as well as nutrient recovery from wastewater streams and earned Masters in Civil Engineering.
- Began career with Seven Seas Water in St. Croix and then became plant manager for 2 MGD SWRO plant in Curacao. Now, regional manager of USVI Operations, managing 6 plants and 7 MGD of SWRO production capacity and 0.75 MGD of Ultra Pure Water production capacity.

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Ultra Pure Water – Uses and Requirements

ULTRA PURE DEFINITION

- Typically measured in resistivity (10 mega-ohm or greater) or Conductivity (0.1 microsiemens/ cm or lower)
- Some specialized systems have further requirements for specific ions (boron, CO_2, etc.)
- UPW is unstable when exposed to atmosphere as it is not in equilibrium with vapor phases.

ULTRA PURE WATER USED IN

- Boiler Feed Water
- Emissions control systems
- Medical Uses - Dialysis
- Electronics Manufacturing
- Pharmaceutical Manufacturing

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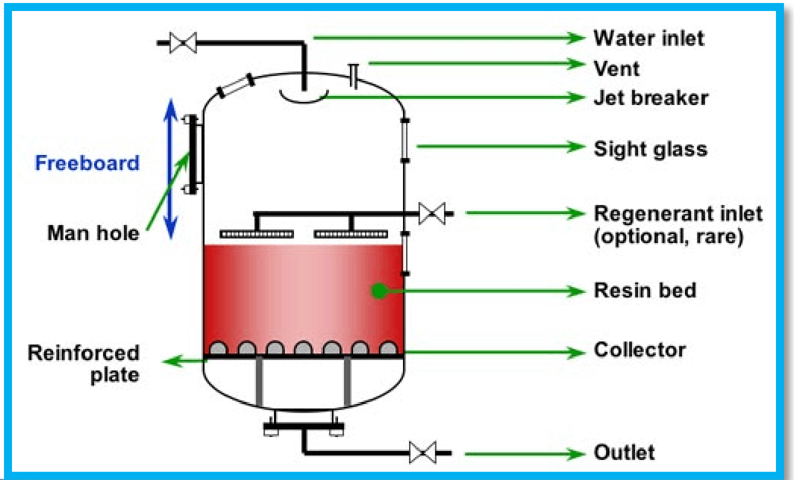
MIXED BED DEIONIZATION

- charged cationic and anionic resins used to exchange hydrogen and hydroxyl (combine to form water) ions for charged ions in a feed water stream
- As the feed water passes through the beds, ions exchanged and a highly pure product is discharged.
- Resins become exhausted as they collect more and more ions. Once fully exhausted the resins must be regenerated and this regeneration is accomplished by using acids and caustic to strip the collected ions from the resins and replace again with hydrogen and hydroxyl ions.



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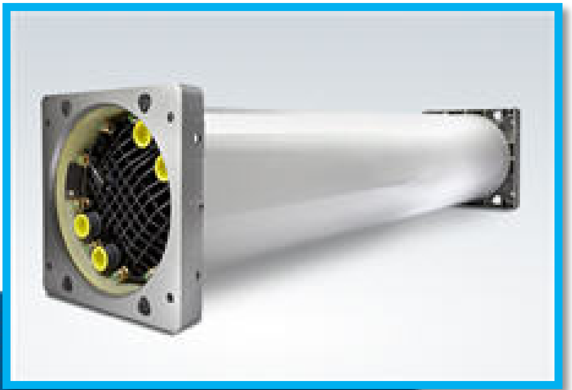
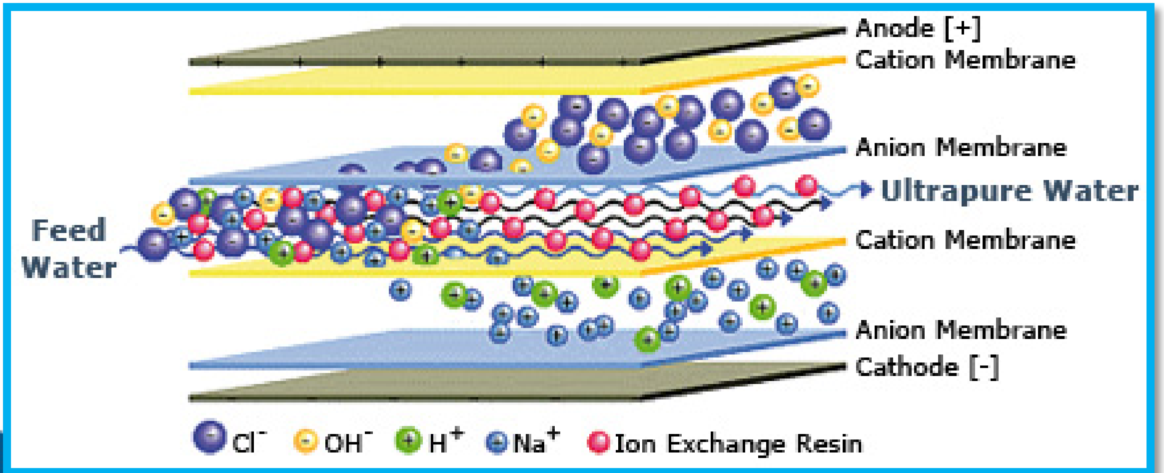
CONTINUOUS ELECTRO DEIONIZATION

- CEDI process also uses charged anionic and cationic resins to attract ions from a feed water stream.
- resins for the CEDI units are developed and selected for their ability to transport ions along the resin surface rather than the resin beads capacity to accumulate ions
- The CEDI process also uses ion selective membranes, both cationic and anionic which selectively allow the passage of the ions. Charged electrodes attract ions across the resin surfaces and through the ion selective membranes into concentrate streams.
- Continuous DC electrical current applied to both the positive and negative electrodes causes continuous transport of ions along the resin and through the ion selective membranes and into the concentrate stream. Ions do not accumulate on the resins and they are in effect continuously regenerated.





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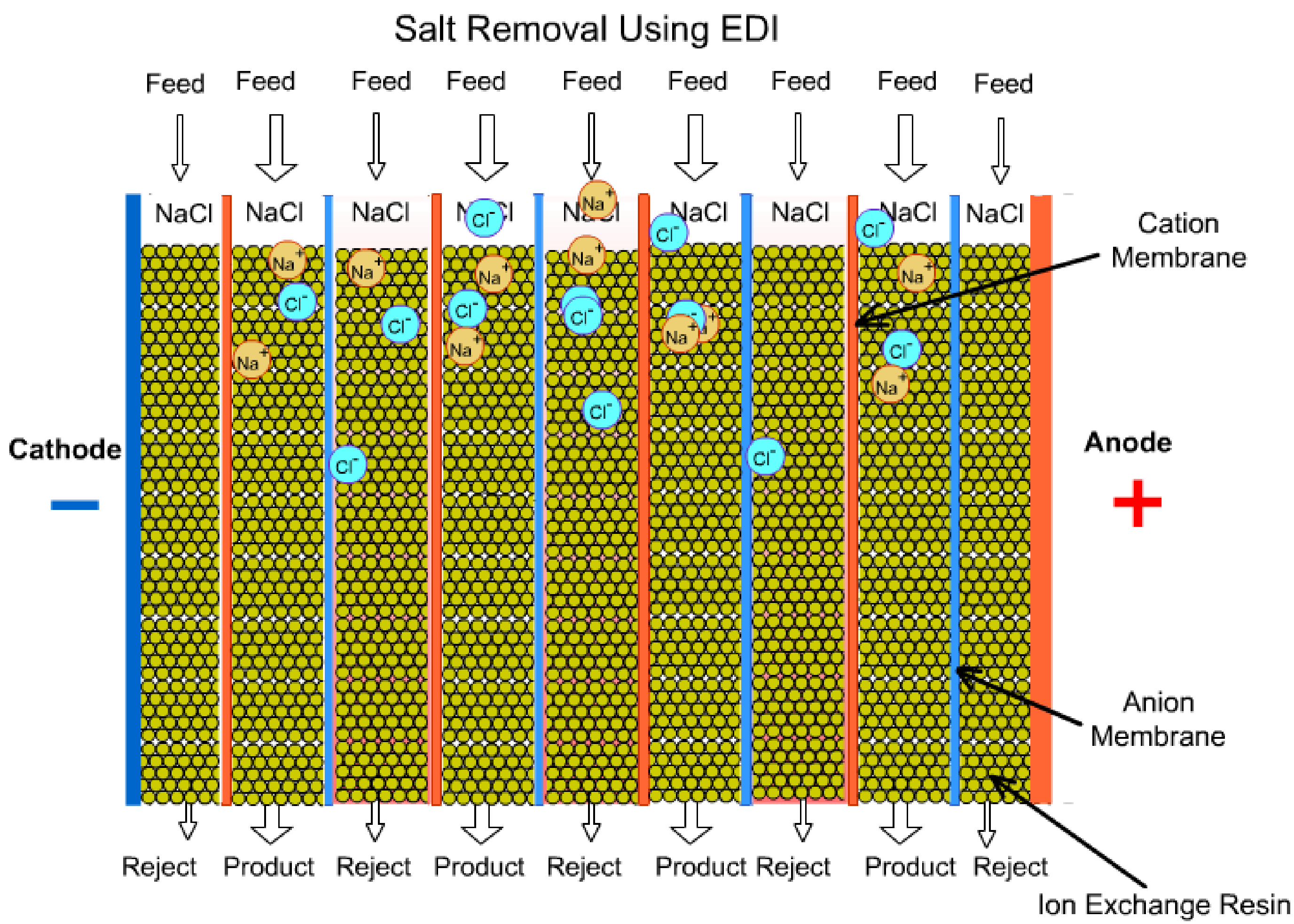

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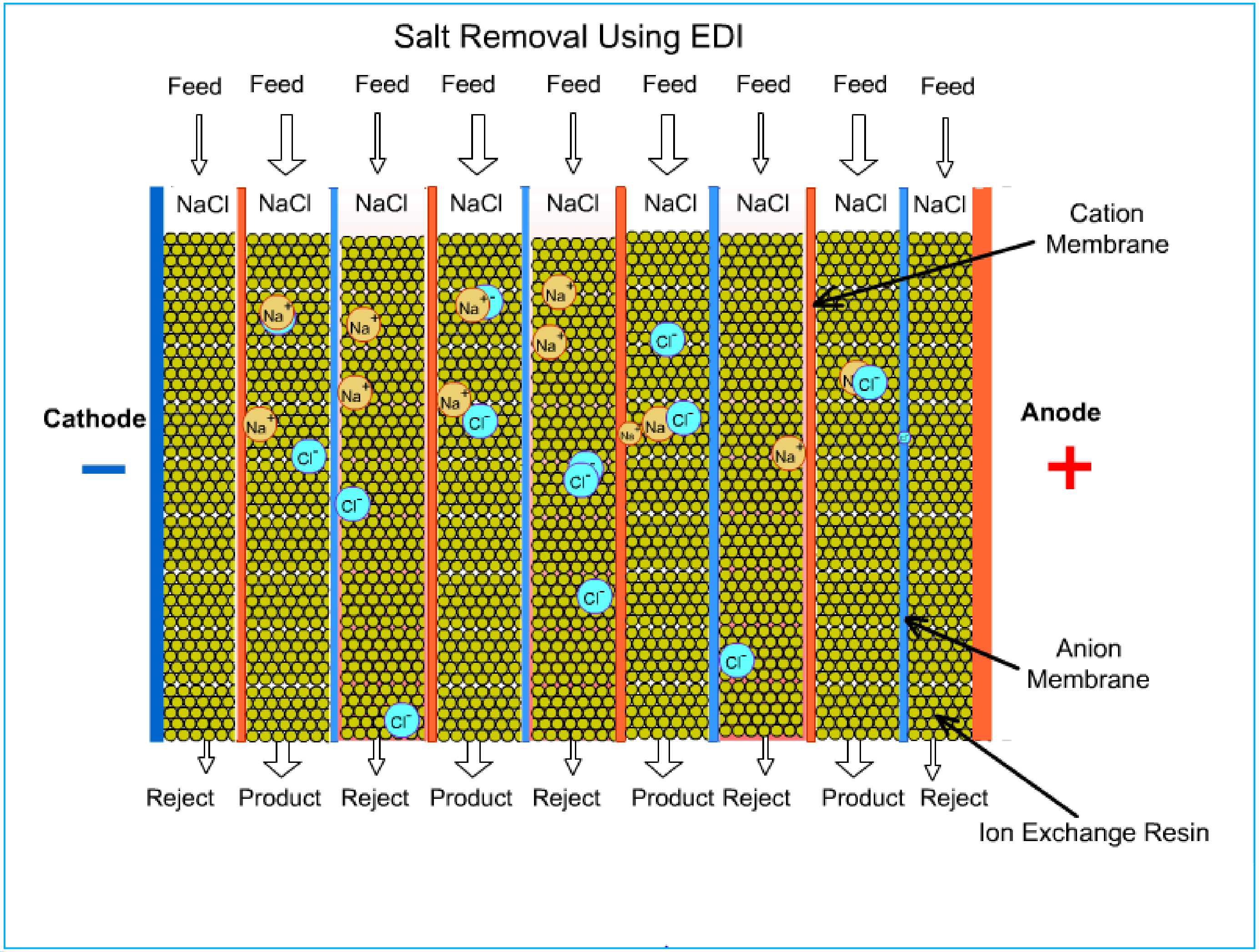
Salt Removal Using EDI
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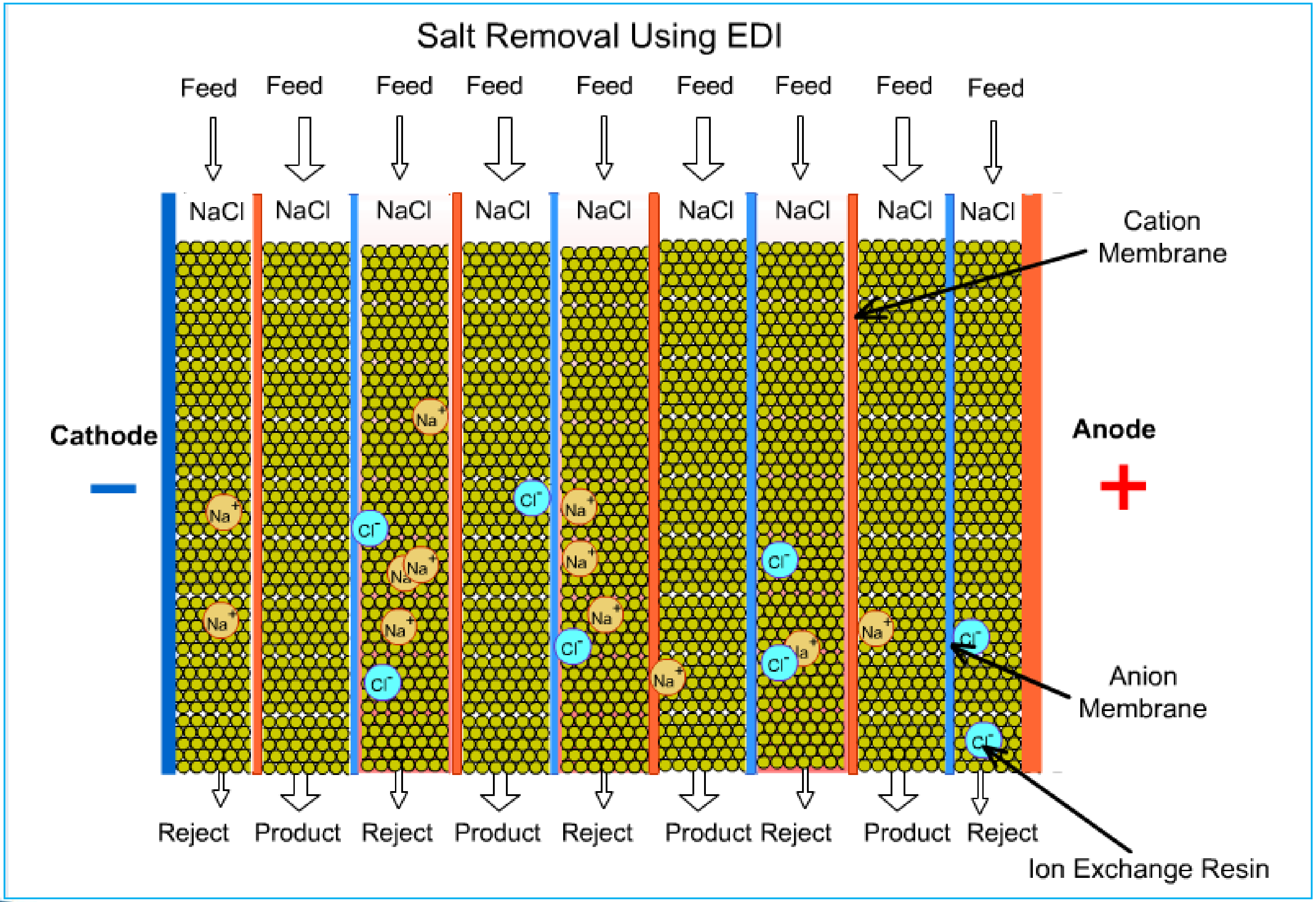
Reject
Product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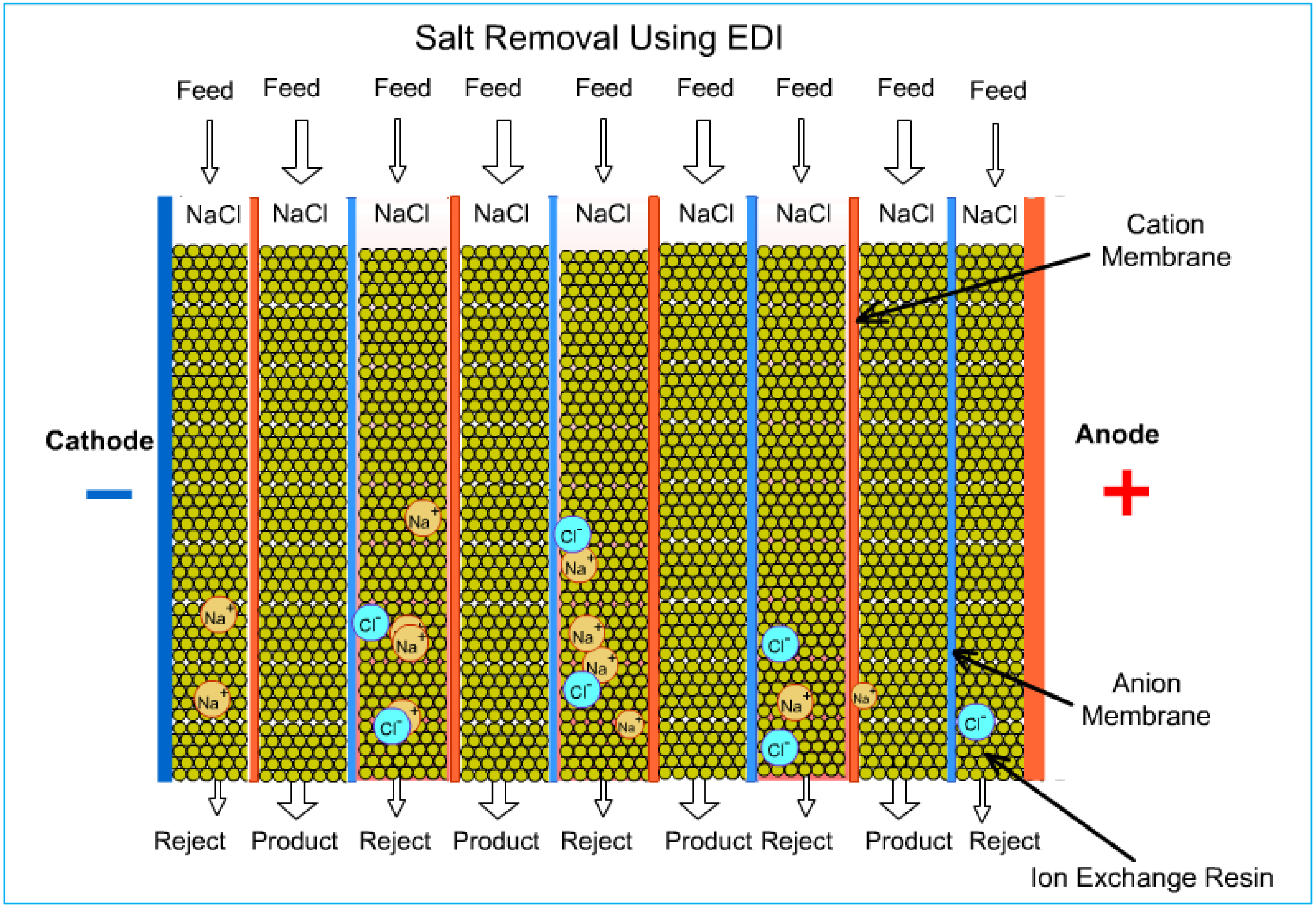
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Ultra Pure Water – Technologies

COMPARISON OF TECHNOLOGIES – PERCEIVED ADVANTAGES OF CEDI

- As the name implies, the CEDI process is continuous and does not require shut downs for regeneration of resins. This results in less downtime and disruption to downstream processes.
- CEDI does not require chemicals for regeneration, eliminating safety concerns for handling and storage of strong acids and bases.
- Elimination of chemical requirements eliminates the shipping and transportation expenses for facility operators.
- Materials and labor costs are reduced and operating expenses almost exclusively consist the cost of power.
- CEDI has a reduced footprint
- There is no "breakthrough" of ions when resins become exhausted and no discharge of regenerate chemicals after regeneration of the beds.

Caribbean Installation of CEDI

TWO SYSTEMS INSTALLED IN USVI

- Virgin Islands Water and Power Authority (VIWAPA) chose to upgrade to the CEDI process and contracted Seven Seas Water to design, build and operate UPW plants on both St. Thomas and St. Croix
- Both UPW plants begin with potable water produced by Seawater Reverse Osmosis system with influent conductivity of 400 – 500 microsiemens/ cm
- Feed water is put through a three-stage single pass brackish water reverse osmosis system with a product of 5-10 microsiemen/cm
- This BWRO product is then delivered into the CEDI process where the de-ionization process provides a product of conductivity 0.1 microsiemens/cm or less (resistivity of 10 mega-Ohms or more).

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Caribbean Installation of CEDI

KEY OPERATING DATA FOR TWO USVI SYSTEMS

•Electrical Consumption:	Approximately 14 kWh/ 1000 gallons (From Seawater to Ultra Pure)
•Electrical consumption:	3-4 kWh/ 1000 gallons (UPW Plants – from potable water to Ultra Pure)
•BWRO System Rejection:	Approximately 99%
•EDI System Rejection:	Approximately 98.5%
•BWRO System Recovery:	90%
•EDI System Recovery:	92%
•Total System Recovery:	83%
•Total System Rejection:	99.9%

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Caribbean Installation of CEDI

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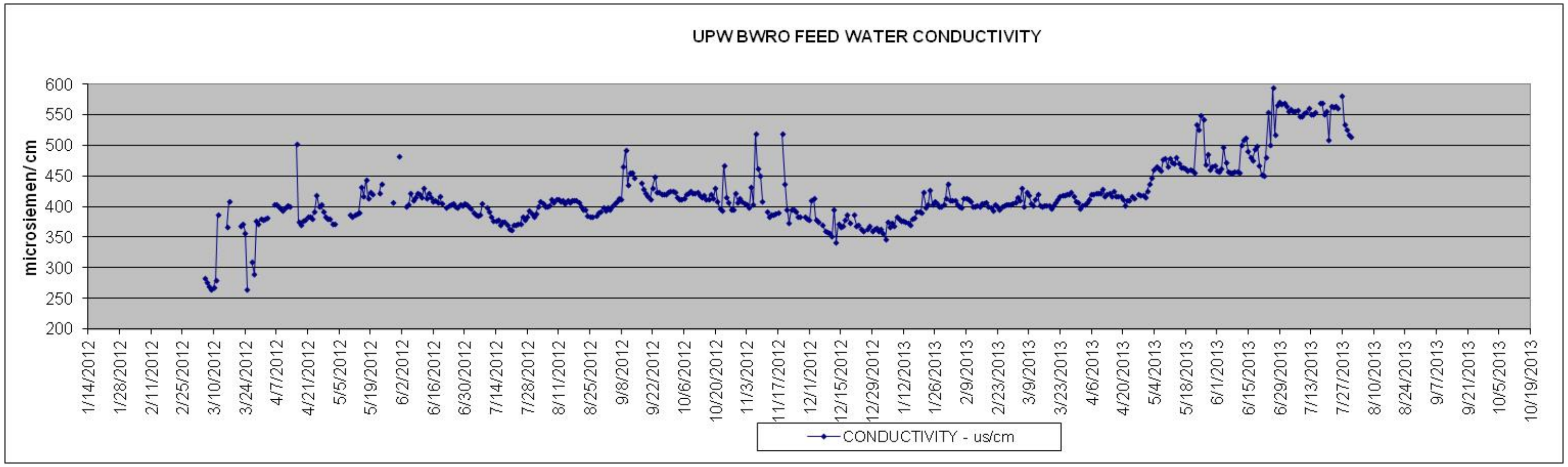
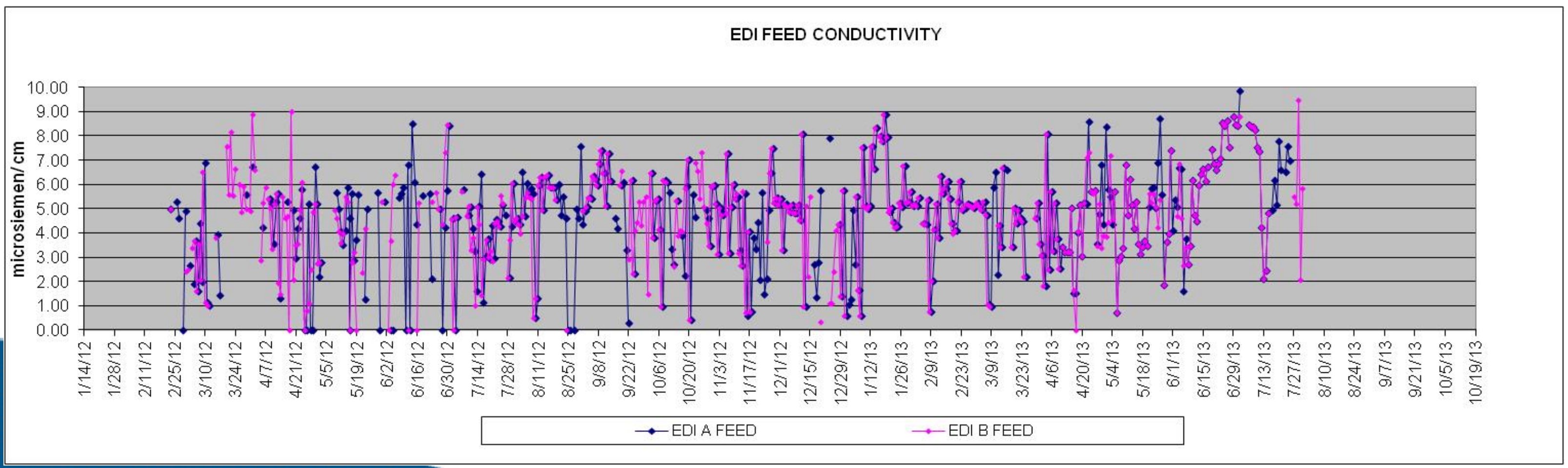
BWRO Performance Data – Feed to CEDI





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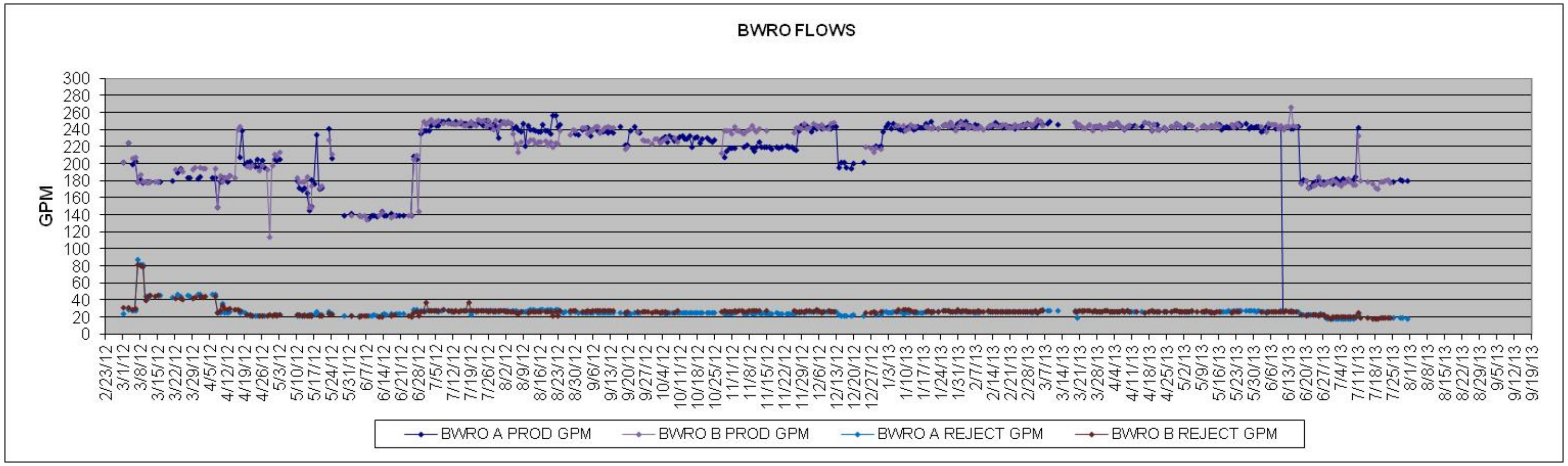
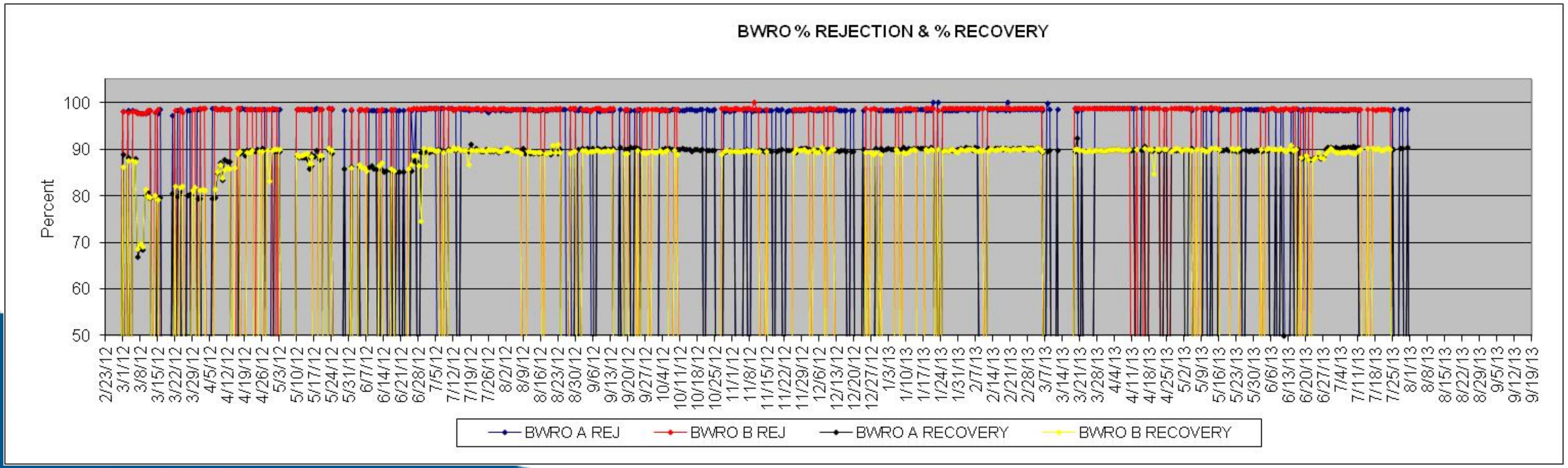
BWRO Performance Data – Feed to CEDI





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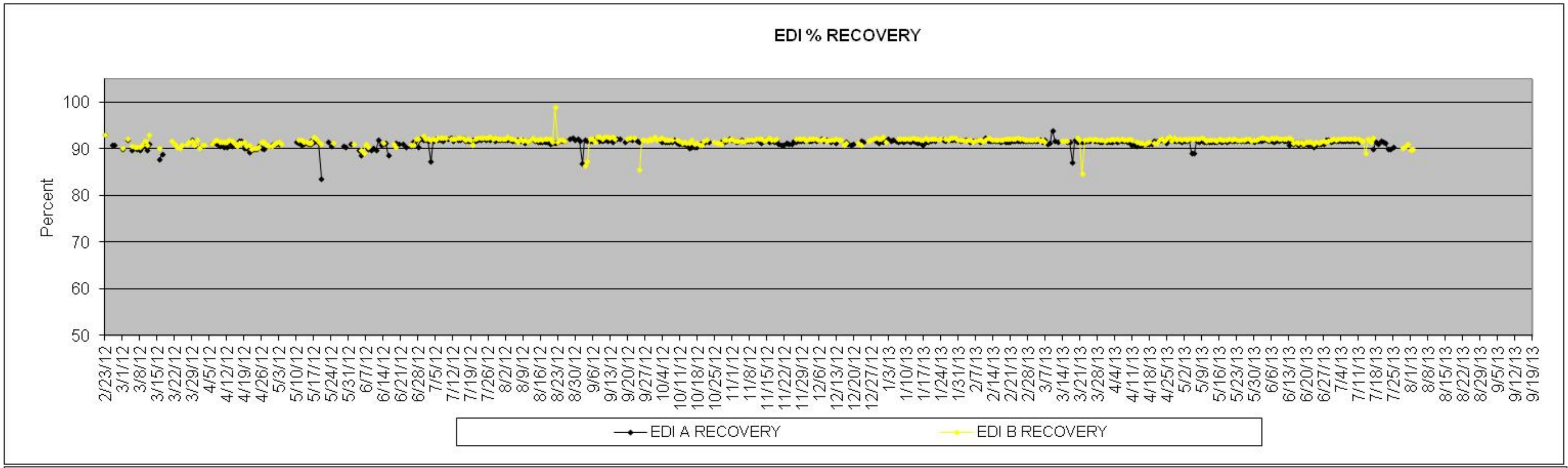
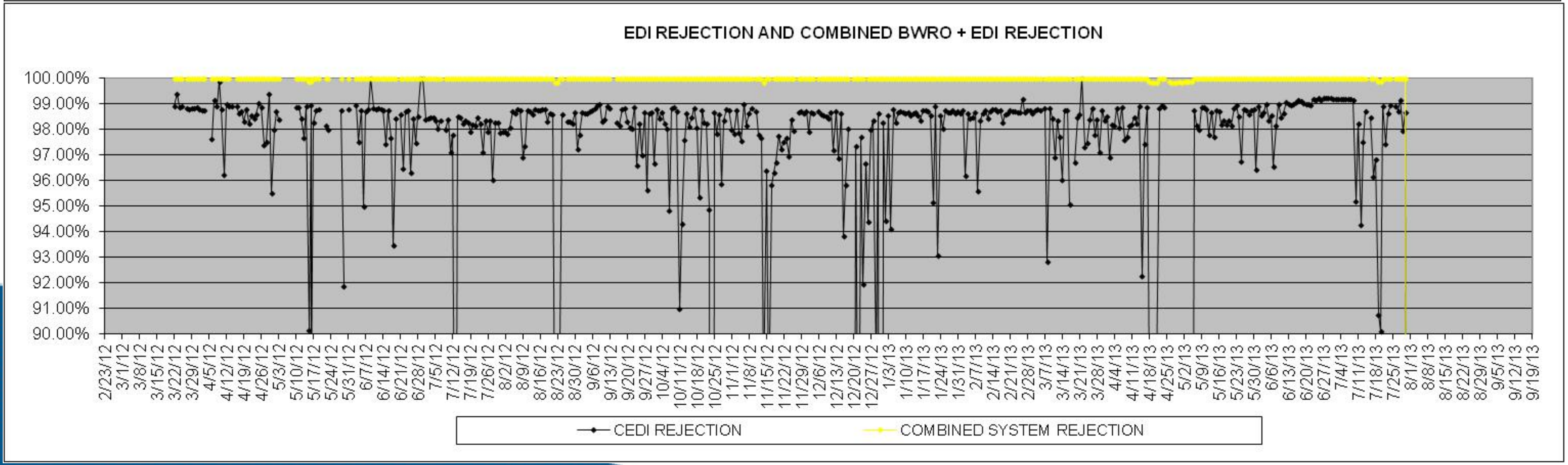
CEDI Performance Data





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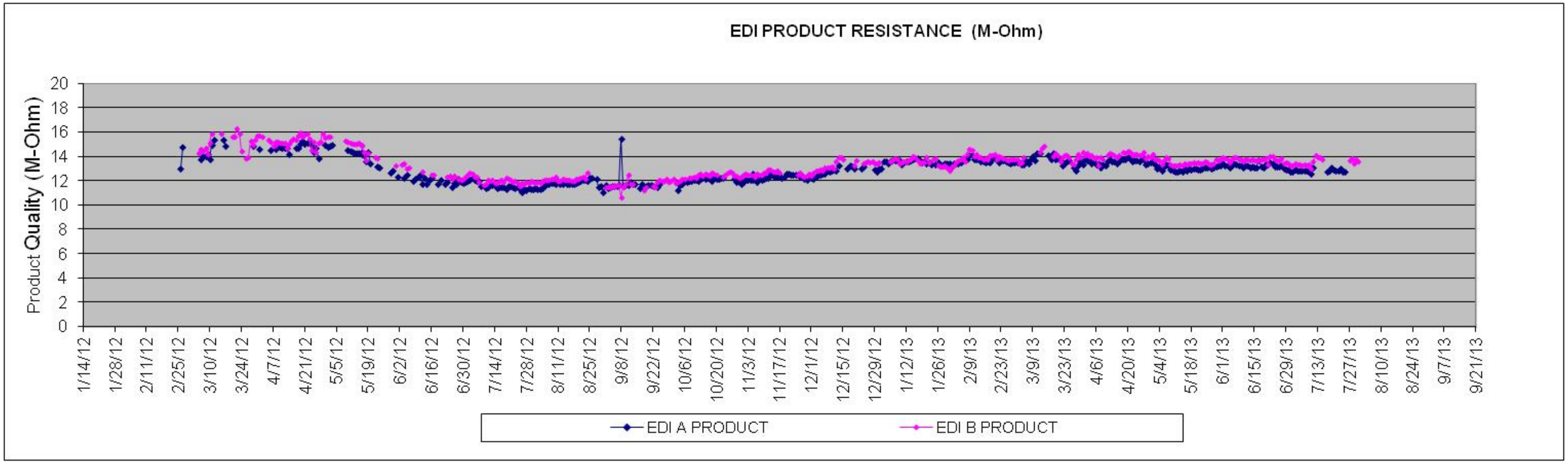
CEDI Performance Data



THE ULTIMATE TEST FOR THE CEDI SYSTEMS

- Consistency and reliability of product water meeting specifications for quality and volume has been exceptional.

Operations and Maintenance

DISCUSSION OF KEY OPERATIONS AND MAINTENANCE POINTS

- O&M on CEDI Units is NOT labor intensive– We staff the CEDI units daily to collect operational data and monitor the system. This is averages a half hour per day, most time spent in recording and entering operational data.
- Variability in product demand is the single factor that contributes to need for operational adjustments to the systems
- In approximately one and a half years of operations at the STT plant, the CEDI units have been 100% available with no planned or unplanned downtime.
- The entire STT UPW system (BWRO + UPW) has had a few of instances of unplanned downtime (leak in cartridge filter housing, BWRO inlet pressure switch failure, VFD enable control relay failure). Due to parallel installation of BWRO units and CEDI units, delivery to customer could continue.
- There have been no quality issues.
- There has been no interruption of service for any type of maintenance to the CEDI resins or other CEDI equipment.
- Operational costs consist almost entirely of electricity – (approximately 3 – 3.3 kWh/ 1000 gallons produced)

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Operations and Maintenance

DISCUSSION FUJI PHOTOFILM STUDY ON OPERATING AND CAPITAL COSTS

- FUJI Photofilm (Matzan, et al., 2001) published a paper outlining a comparison of CEDI to mixed bed Capital and Operating Costs with a wealth of quality comparative data. The pilot study and cost comparisons were conducted at Fuji's Greenwood, South Carolina facility.
- Total capital costs were evaluated including equipment purchase (Table B), ancillary equipment purchase associated with chemical regeneration systems (Table C) and additional "Facilities" costs associated with civil and infrastructure work to accommodate the system (Not Shown).
- End Result: 22% savings on CEDI installation over Mixed Bed technology, (Matzan, et al., 2001)

TABLE B
Comparison Costs

System	*Cost*
RO/IX	
● Single-pass RO system, two trains rated at 265 gpm permeate rate.	
● Granular activated carbon system, two parallel three-column trains rated at 330 gpm per train.	
● Mixed-bed deionization system, three trains rated at 250 gpm.	$1,015,221
RO/EDI	
● Single-pass RO system, two trains rated at 265 gpm permeate rate	
● Granular activated carbon system, two parallel three-column trains rated at 330 gpm per train.	
● EDI system, two trains rated at 250 gpm.	$925,608

TABLE C
Ancillary Facilities Cost

System	*Cost*
● Bulk chemical supply for regeneration (i.e., sulfuric acid and sodium hydroxide).	$57,690
● Neutralization tank with pH monitoring and control	$18,350
● Regeneration skid, with sodium hydroxide heat exchanger for heating caustic, and sulfuric acid heat exchanger for cooling acid.	$43,950
● Total ancillary costs	$119,990

REFERENCE:

Matzan, Eric; Maitino, Phil; Tate, Jeff; Deionization – Cost Reduction and Operating Results of an RO/EDI Treatment System; Ultrapure Water Expo, October 2001

Operations and Maintenance

DISCUSSION FUJI PHOTOFILM STUDY ON OPERATING AND CAPITAL COSTS

- The Fuji study continued to operating cost comparisons between the CEDI and Mixed Bed technology.
- Again the study found the CEDI system to be cost effective in comparison to mixed bed technology.

TABLE D
Mixed-Bed Cost per Year

Item	*Cost*
Acid	$2,102
Caustic	$13,140
Manpower	$4,088
Waste Water	$6,137
Resin	$5,820
Total:	$31,267

TABLE E
Annual EDI Cost

	Estimated with Brine	*Estimated w/o brine*	*Actual w/o Brine*
Electrical	1.6 kw-hr/kgal	2.4 kw-hr/kgal	2.6 kw-hr/kgal
Consumption	$5,172	$7,758	$8,405
Cost of Brine	$234	$0	$0
Manpower	$2,044	$2,044	$2,044
Waste Water	$0	$0	$0
Stack Replacement	$16,800	$16,800	$0
Total:	$24,250	$26,602	$10,449

REFERENCE:

Matzan, Eric; Maitino, Phil; Tate, Jeff; Deionization – Cost Reduction and Operating Results of an RO/EDI Treatment System; Ultrapure Water Expo, October 2001

CEDI in the Caribbean

REVIEW OF TYPICAL ADVANTAGES OF CEDI AND APPLICABILITY TO THE CARIBBEAN

- As the name implies, the CEDI process is continuous and does not require shut downs for regeneration of resins. This results in less downtime and disruption to downstream processes. Advantageous anywhere, Caribbean no exception.
- CEDI does not require chemicals for regeneration, eliminating safety concerns for handling and storage of strong acids and bases. Applicable to the Caribbean with limited space, sensitive environments.
- Elimination of chemical requirements eliminates the shipping and transportation expenses for facility operators. Extremely advantageous for Caribbean Operations where shipping costs are a large part of chemical costs.
- Materials and labor costs are reduced and operating expenses almost exclusively consist the cost of power. Maybe not an advantage in Caribbean, where power is often quite expensive. However, if UPW need coincides with power generation, becomes quite reasonable to include this as an advantage in the Caribbean as well.
- CEDI has a reduced footprint . Many power generation facilities in the Caribbean are on limited space and reduced footprint allows for expansion and upgrade of other equipment.
- There is no "breakthrough" of ions when resins become exhausted and no discharge of regenerant chemicals after regeneration of the beds. Lifecycle costs of consistently high quality boiler feed waters are difficult to quantify but significant to the long term operation of boilers, turbines, etc. Consistent high quality product means consistent operations of downstream equipment.

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CEDI in the Caribbean

THE MAJOR ADVANTAGES FOR TRANSITION TO CEDI

•The CEDI process was developed in the mid 1950's and units have just become commercially available in the late 1980's.   There has been a continuous drop in capital costs for the CEDI units as well as operating costs.

•A study has estimated 15% savings in operating costs and 22% savings in capital costs comparing CEDI units to traditional mixed bed units (Matzan et al., 2001).

•No Neutralization – No Permitting for discharge

•No chemical containment, chemical storage

•Safety

•Consistency of Product

•Intangible Costs - Equipment Damage, Worker Safety, Environmental Regulation

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