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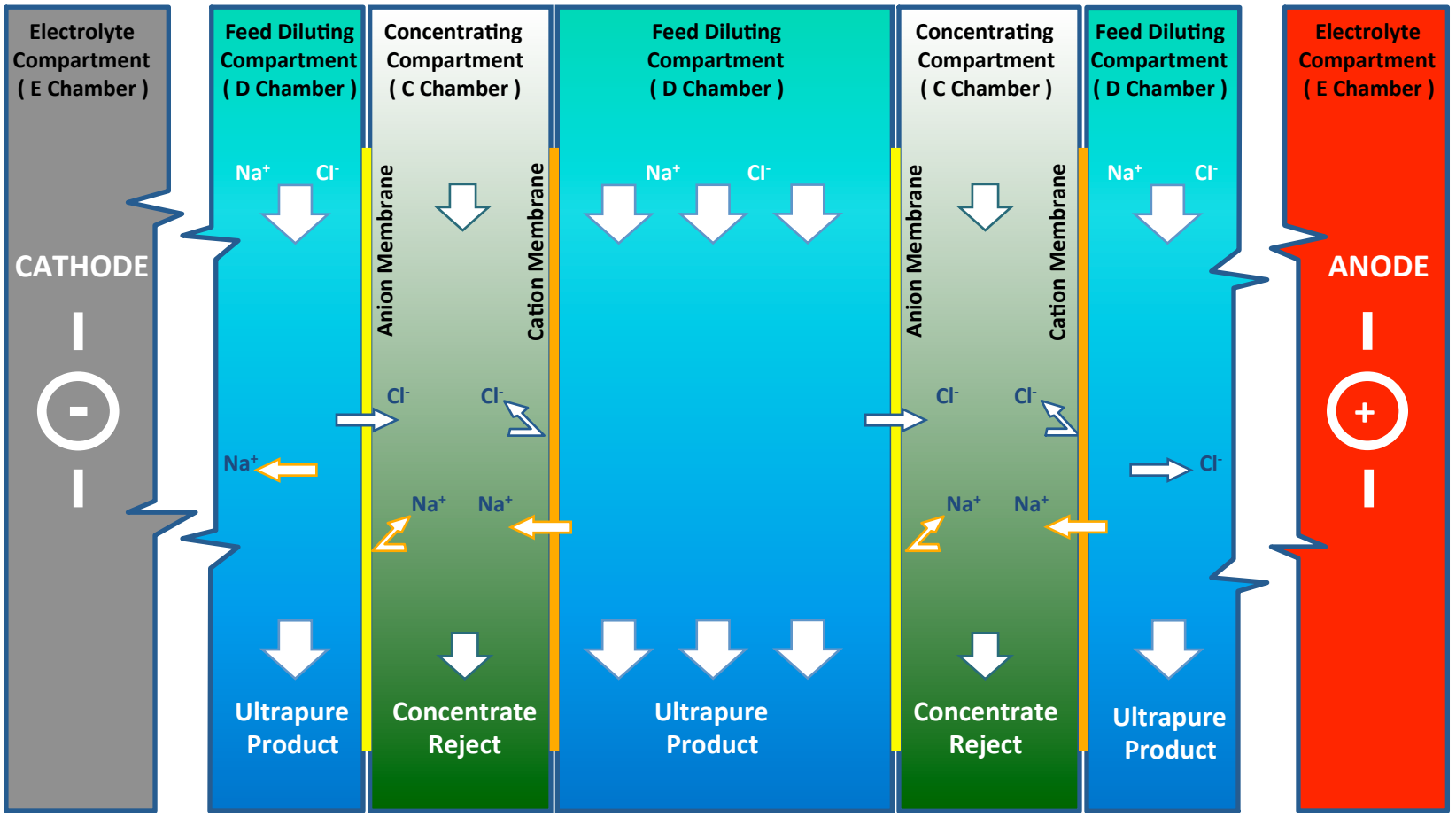
CONTINUOUS ELECTRO DE-IONIZATION

CEDI

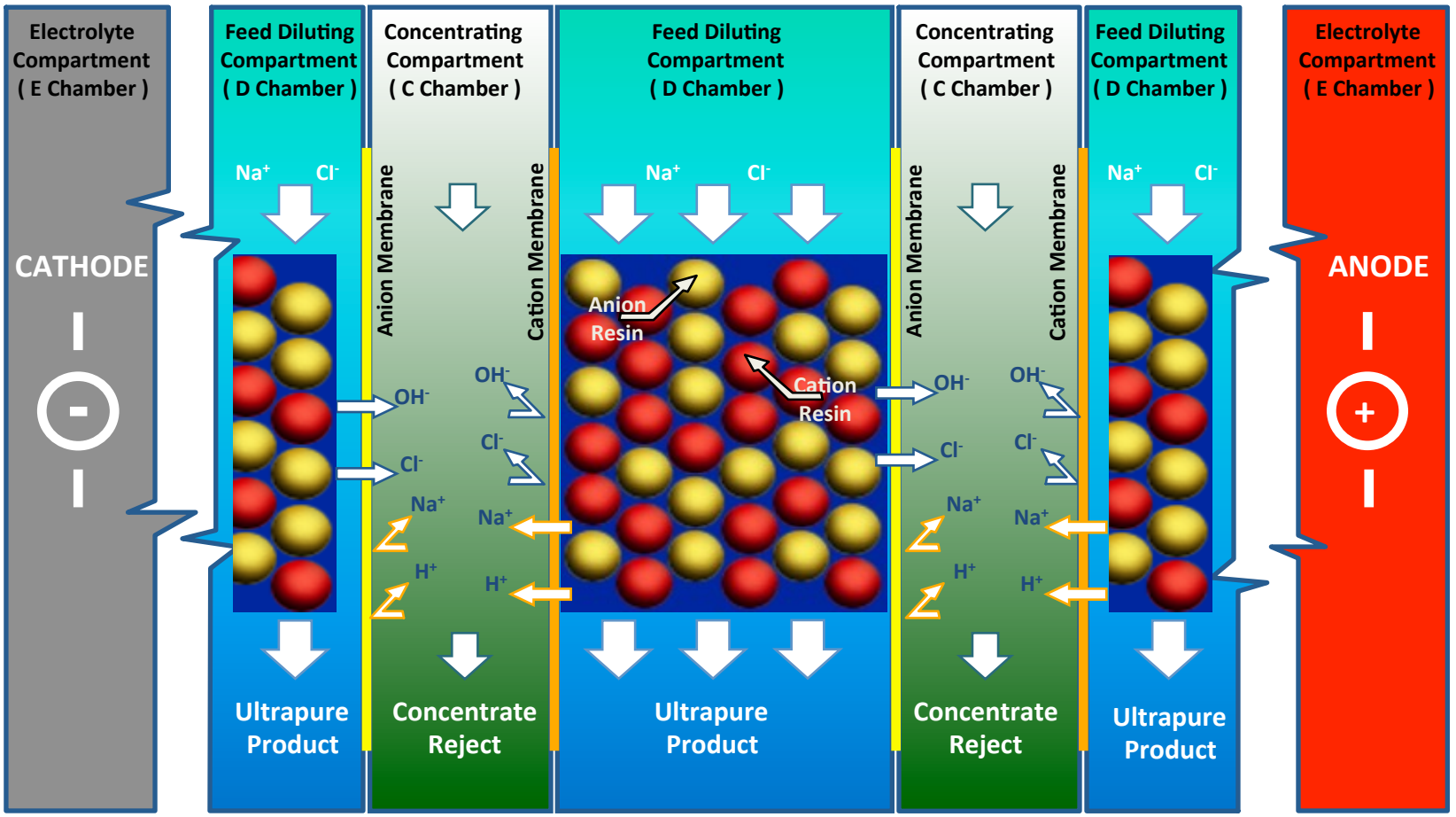
Sürekli Elektro De-İyonizasyon

Ruşen Eşref YAZGAN

EDI


Flow
Electrolyte Compartment (E Chamber)
Feed Diluting Compartment (D Chamber)
Concentrating Compartment (C Chamber)
Feed Diluting Compartment (D Chamber)
Concentrating Compartment (C Chamber)
Feed Diluting Compartment (D Chamber)
Electrolyte Compartment (E Chamber)
CATHODE
ANODE
Anion Membrane
Cation Membrane
Anion Membrane
Cation Membrane
Na+
Cl-
Ultrapure Product
Concentrate Reject
Ultrapure Product
Concentrate Reject
Ultrapure Product

EDI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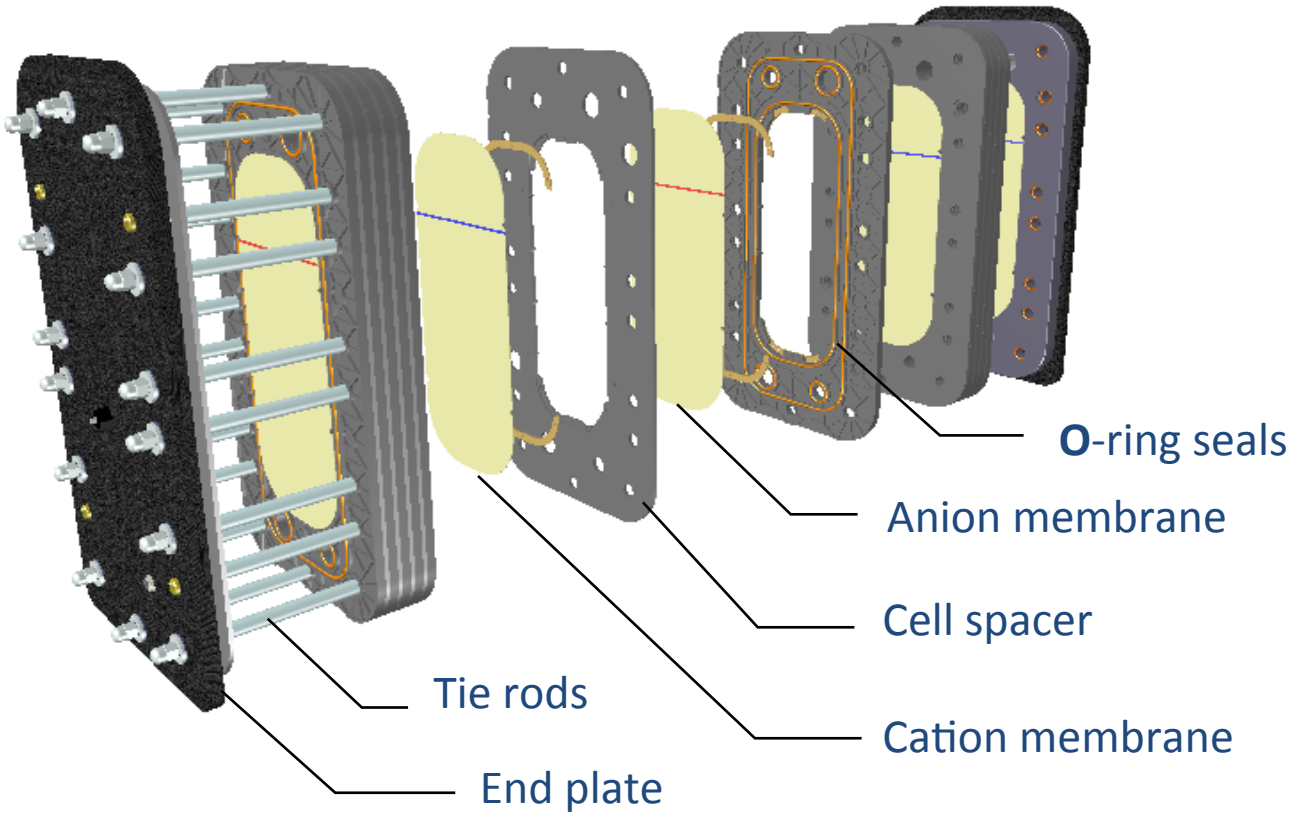
CATHODE
ANODE
Anion Membrane
Cation Membrane
Anion Resin
Cation Resin
Na+
Cl-
OH-
H+
Ultrapure Product
Concentrate Reject
Ultrapure Product
Concentrate Reject
Ultrapure Product

EDI

Construction



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Ion Exchange Membrane

Making:

Polyethylene powder mixed with ion exchange resin.

The mixture is extruded similar to plastic foils.

Characteristics:

- Membranes are watertight
- Driving force for moving the ions is the electrical field
- Ions can only move through the membrane with similar charge

  Cations through cation exchanger membrane

  Anions through anion exchanger membrane

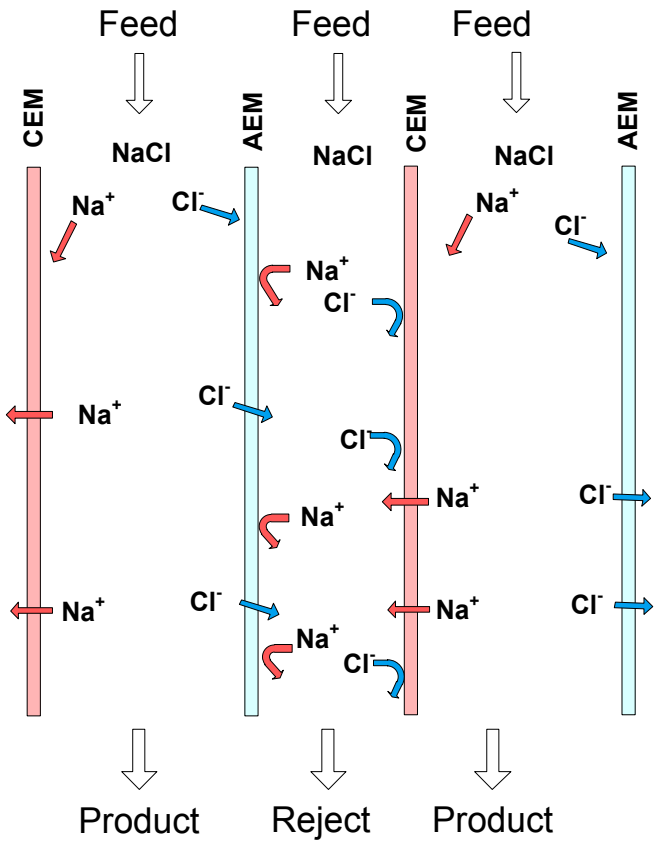
EDI

Ion Exchange Membrane

OH^- ions are generated

pH > 12

cathode



H^+ ions are generated

pH < 3

anode

AEM : Anion Exchanger Membrane

CEM : Cation Exchanger Membrane

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Ion Exchange Resin

- Ion-exchange resin in the compartments improves the transport of the ions and the influence of the electrical field.
  Ultrapure water in the electro de-ionization (EDI) stack has very low electrical conductivity.
  That means high resistivity; hence, no current flow will occur without the support of the ion-exchange resin.
- Ion-exchange resin leads to splitting of water H^+ and OH^- on the resin surface.
  With H^+ and OH^- ions, the resin will be regenerated continuously.
- Based on high pH, caused by OH^- ions, the weak acids CO_2, SiO_2 and Bor can be removed.
- Resin capacity is not the most important characteristic.
  The main purpose of the resin is only to support the ion transport.
- Based on the capacity of the ion exchanger, the EDI stack is able to work.
  That enables desalination for some hours without power.

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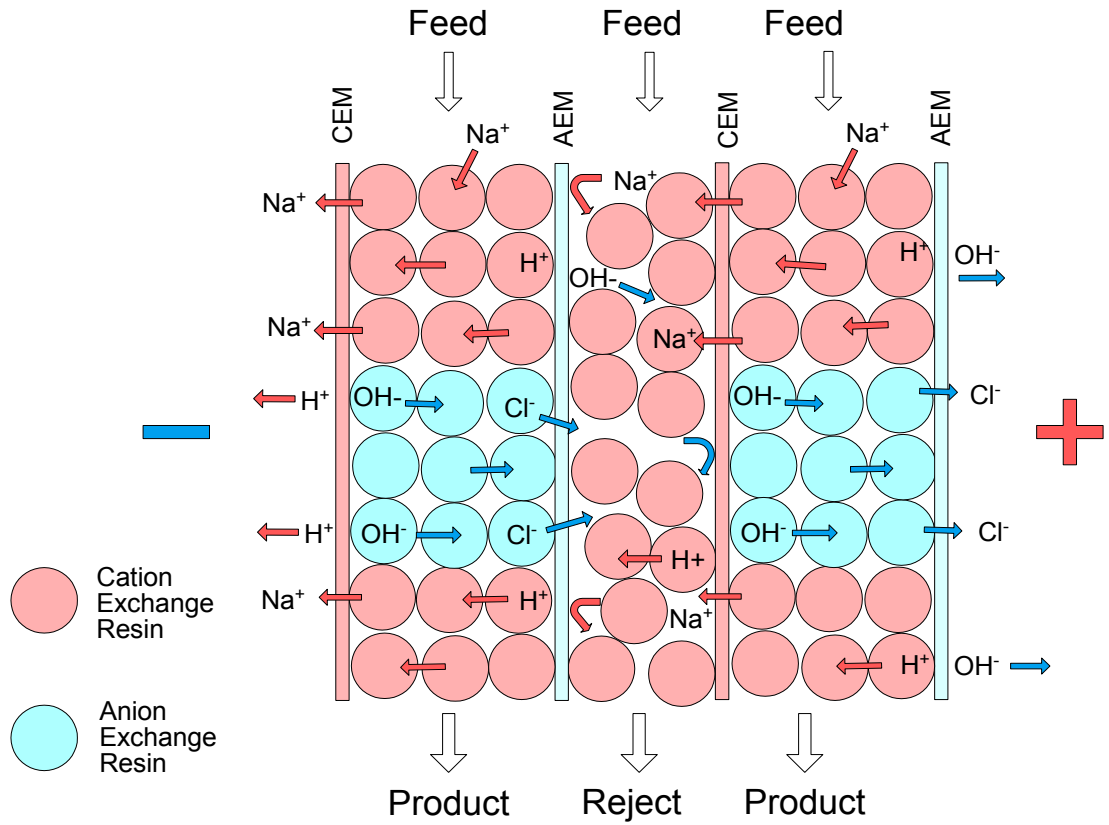
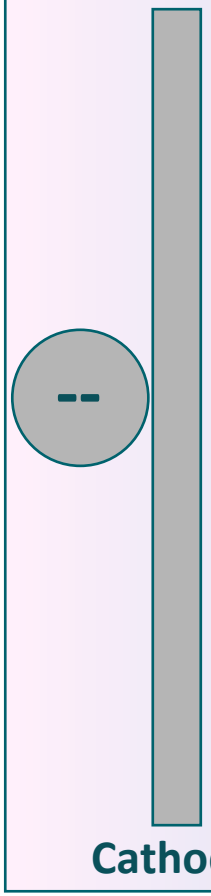
EDI

Ion Exchange Resin



EDI

Chemical Reactions at the Cathode



$$2H_2O + 2e^- = 2OH^-(aq) + H_2(g)\uparrow$$

- Generation of Hydrogen
  - 7.0 mL/Amp/minute
    = 1.89 l/h H_2 / Stack
- High pH value, caused by OH^- ions
- Residual hardness (calcium or magnesium) will precipitate and lead to scaling on the membrane

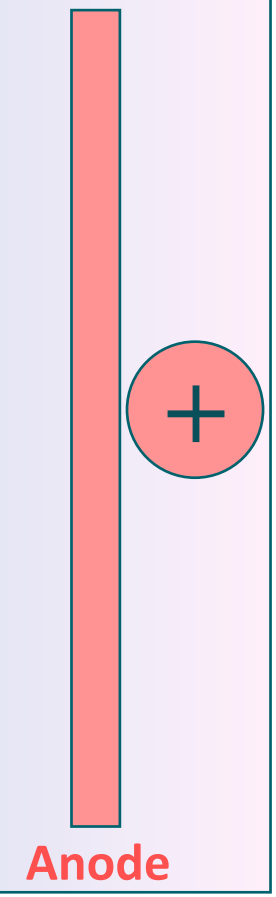
EDI

Chemical Reactions at the Anode

$2H_2O = 4H^+(aq) + O_2(g)\uparrow + 4e^-$

$(2Cl^-(aq) = Cl_2(g)\uparrow + 2e^-)$

- Generation of oxygen
  - 3.5 mL/Amp/minute
- Chlorine gas will be generated
  - 1-2 ppm in E_{out} (@400 µS/cm NaCl)
- Low pH value, caused by H^+ ions



EDI

Ultra Pure Water quality is affected by:

Flow rate -- higher the flow rate,
lower the dilute quality

Temperature -- lower the temperature,
lower the dilute quality

Carbon dioxide -- higher the CO_2 content,
lower the dilute quality

Current -- higher the amperage,
better the dilute quality,
better the removal of weak acids, CO_2 and SiO_2

EDI

Benefits

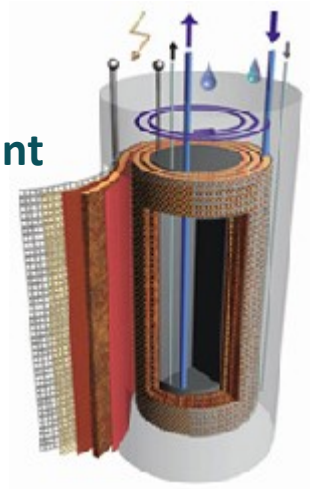
- Compact design, low space requirement
- Pure water conductivity approx.
  0.1 - 0.2 µS/cm
- Recovery of 90 - 98 %
- Reduction of TOC, (ionized bacteria and endotoxins)
- Low pressure loss $\Delta p < 3$ bar
- Pressure proof up to 7 bar, no leakage
- Necessary voltage approx. 100 - 400 V DC
- Lifetime of modules approx. 5 years

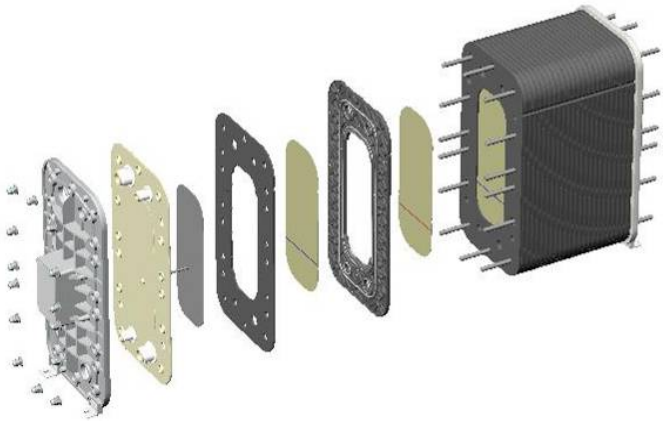
FDA: U.S. Food and Drug Administration
TOC: Total Organic Carbon

EDI

Advantages of Plate Design to Spiral-Wound Design

- No need of concentrate recycle to increase conductivity leads to
  - No risk of scaling and chlorine build-up in concentrate compartment
  - No risk of microbiological contamination
  - Concentrate compartment incl. in hot water sanitization cycle
- Higher stability against pressure and temperature fluctuations
- Safety valve upstream EDI to avoid pressure hammers
- Longer average lifetime of EDI modules: 5 years
- EDI Stack with FDA declaration of conformity





FDA: U.S. Food and Drug Administration

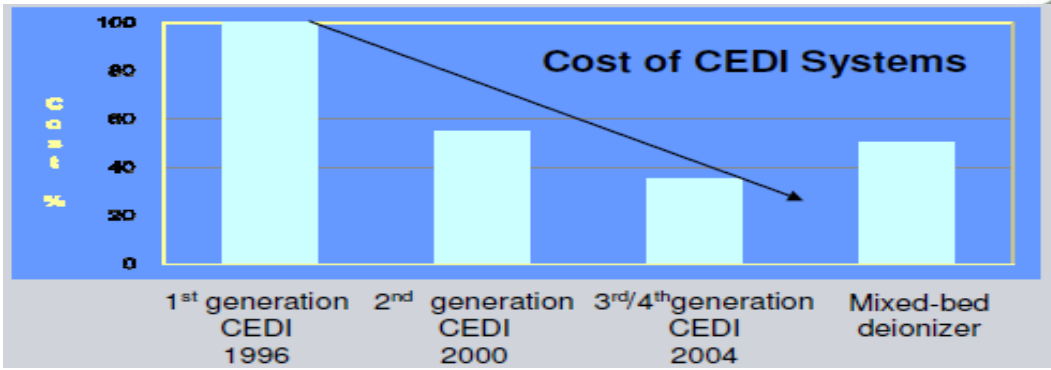
EDI

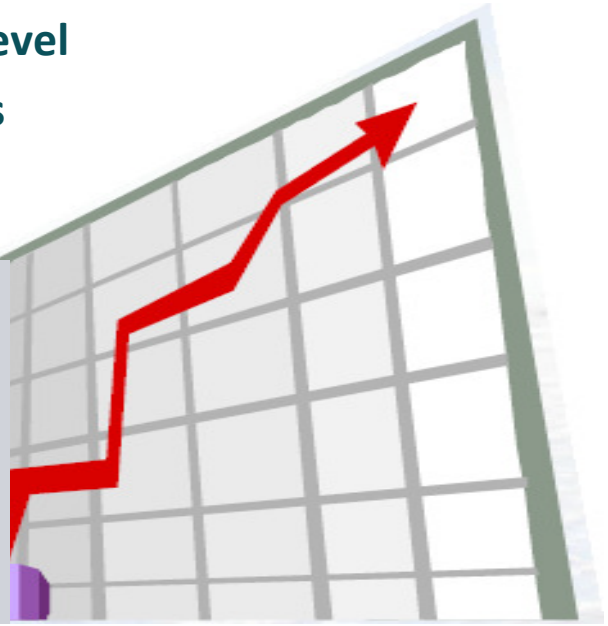
A Current Look at Electro De-Ionization Market

Sale of Electro de ionization systems worldwide has increased.

(Continuous) Electro de-ionization (CEDI) is:

- -- **Accepted as a replacement of existing Mixed Bed Ion eXchange systems**
- -- **Commonly specified as an option on new de-ionization systems**
- -- **Now equal to cost of two-pass RO on a system level**
- -- **Combination technology systems, RO/CEDI units**
- -- **Footprint savings**





EDI

CONTINUOUS EDI VS MBDI

Evolution of De-Ionization

CEDI: Continuous Electro De-Ionization
MBDI: Mixed Bed De-Ionization
RO : Reverse Osmosis

- 1st Generation

Systems based on chemically regenerated ion exchange resins;
the mixed-bed stage was preceded by separate units for both cation and anion exchange.

- 2nd Generation

The need for reduced Total Organic Content (TOC) began the change to Reverse Osmosis (RO), which used membrane technology to dramatically reduce chemical usage in water treatment systems.

- Current Generation

The combination RO + continuous electro de-ionization (CEDI) has made the total elimination of regeneration chemical and brought other benefits.

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CONTINUOUS EDI VS MBDI

Facts About Electro De-Ionization

- Electro de-ionization is a polishing technology.
  CEDI requires RO pretreatment.
  If RO is not present, CEDI is usually not viable.
- Not all CEDI is the same.
  The CEDI suppliers vary widely in terms of experience, product performance, robustness and operability.
- Some product quality specifications may be difficult to achieve.

  -- Some low levels of Sodium and Silica (ppb) can be challenging if the feed is too high. (must be confirmed with projection software and experience).

  -- In some cases, to use a CEDI, a two pass RO is required for pretreatment.
- High hardness in the feed-water leads to scaling. Requires more frequently cleaning and/or possibly a pre-RO softener.
- Unfortunately, early adopters of CEDI technology were sometimes the victim of misapplication, poor pretreatment design and improper operation.

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CONTINUOUS EDI VS MBDI

Misconceptions About Electro De-Ionization

CEDI systems require a lot of power.	• CEDI systems typically require < 1 kW / 1000 gal (3.78 m^3) Comparison: typically half the power of an RO booster pump
CEDI systems are not robust (compared to MBDI - mixed bed deionization).	• As with MBDI, the more stable the pretreatment, the more stable the operation of the CEDI system. • De-chlorination system problems will damage the RO and MBDI, as well as the CEDI system.
CEDI systems are prone to leaking.	• Some CEDI modules are guaranteed not to leak.

EDI

CONTINUOUS EDI VS MBDI

Misconceptions About Electro De-Ionization

CEDI systems do not make the same quality water as MBDI.	• **CEDI systems can produce equal quality water to MBDI.** • **Ultra low sodium and silica specifications can be achieved with certain CEDI models.**
CEDI systems require constant maintenance.	• **CEDI systems perform much like RO, performance changes gradually over time at which a cleaning is needed. (typically 1-2 times per year)**
CEDI systems cost more than MBDI.	• **With current steel & ion exchange resin prices, the cost of CEDI systems is often less than MBDI systems when all costs are included.**

EDI

CONTINUOUS EDI VS MBDI

Why choose continuous EDI instead of MBDI?

CEDI has advantages in three significant parameters:

O - Operating Cost

- **Cost of Chemicals for regenerations**
- **Cost of Water for regenerations**
- **Cost of Wastewater treatment (including equipment)**

P - Performance

- **Constant quality and production, no need for regenerations**
- **No bad regenerations or unexpected short runs**

S - Space and Safety

MBDI systems require

- **space for equipment,**
- **regeneration system, regeneration chemical storage,**
- **neutralization system, safety showers, etc.**

EDI

CONTINUOUS EDI VS MBDI

More reasons why...

- Allows complete control over water system in house - nothing leaves or enters the plant.
- Consistent multi-megaohm product quality.
- Continuous, high recovery operation.
- Stable water quality over time.
- No regeneration chemicals or regeneration waste created.
- No upsets due to sub-standard regenerations.
- Smaller system footprint creates more facility space.
- Reduction of environmental, health and safety risks.

EDI

CONTINUOUS EDI VS MBDI

Operating Cost Savings

- **With the rising cost of fossil fuels, power plants are looking to reduce their operating cost to maintain the profit levels.**
- **The de-mineralization system is one of the top contributors to plant operating cost**
  - **Chemicals**
  - **Water Usage**
  - **Waste Generation and Treatment**
  - **Labor**

Let's take a closer look at the contributors…

EDI

CONTINUOUS EDI VS MBDI

Cost of Chemicals

- The cost of ion exchange resins and other petroleum based materials have increased.
- A mixed bed de-mineralization plant consists of the anion column and the cation column, which are re-generated by caustic soda and hydrochloric acid, respectively... cost of both have increased.

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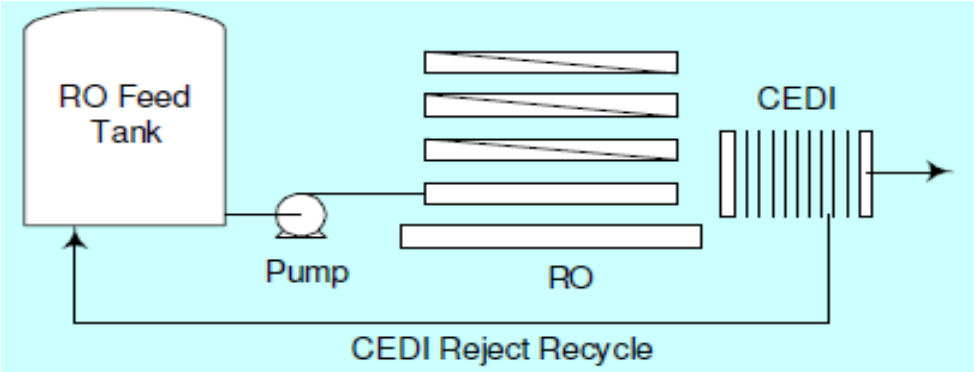
CONTINUOUS EDI VS MBDI

Water Usage, Waste Regeneration

- Electro de-ionization uses electricity instead of chemicals to regenerate.
- No need for regeneration system or neutralization system.
- No need for bulk acid/caustic storage.
- Reject from EDI is better quality than the RO feed water and can be discharged with no treatment.
- Reject from EDI system can be recycled upstream to the RO feed for reuse (which means EDI system is100% recovery, zero waste process).
- Water savings both on the processing and waste ends.



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CONTINUOUS EDI VS MBDI

Labor Savings

- Like RO, continuous electro de-ionization (CEDI) is a constant production and performance process.
- As a result, the manpower to operate a CEDI system is very low, typical requirements are biweekly log readings of the key parameters and a water sample.
- Customer Quote #1: "The VNX CEDI system is so easy to operate; we have taken the demin operator and reassigned him to other more important duties".
- Customer Quote #2: "We used to call the demin system the 'demoralization system' based upon all the problems we had. The CEDI system is a breath of fresh air".

EDI

CONTINUOUS EDI VS MBDI

The Global Trends (Three R's)

Use "Environment Friendly" technologies that are high efficiency and designed to:

-- REDUCE

- **-- Reduce chemical usage**
- **-- Reduce water usage, growing restrictions**
- **-- Reduce waste generated, discharge limits becoming more stringent**
- **-- Reduce bulk chemical handling, focus on plant safety,**

-- RE-USE

- **-- Repair existing equipment or replace with green technologies**

-- RECYCLE

- **-- Recycle upon exhaustion**

EDI

CONTINUOUS EDI VS MBDI

Case story #1 - Small Flow System

System Details:

- **50 gpm (11.4 m^3/h)**
- **11 µS/cm feed water**
- **24/7 operation**
- **2 x 30" dia MBDI**
- **1 VNX system**

MBDI: Mixed Bed De-Ionization

VNX®: Continuous EDI

MBDI SYSTEM OPERATING COST SUMMARY			
Replacement Resin cost	$	6,376	$
Chemical cost per regen	$	35	$/regen
Wastewater cost per regen	$	9	$/regen
Annual manpower cost *	**$**	**6,168**	**$/yr**
Annual resin cost *	**$**	**1,275**	**$/yr**
Annual chemical cost *	**$**	**1,727**	**$/yr**
Annual wastewater cost *	**$**	**444**	**$/yr**
Annual Waste permitting cost	**Not included**		
Annual safety training	**Not included**		
* Calculated			
TOTAL MBDI SYSTEM OPERATING COST $/YR		$9,614	$/yr

VNX SYSTEM OPERATING COST SUMMARY			
Electricity Cost per VNX module per day	$	0.07	$/day
Electricity Cost per VNX Skid	$	0.07	$/day/skid
Chemical cost per clean	$	100	$/clean
Wastewater cost per regen	None		$/regen
Annual module cost per skid*	**$**	**1,875**	**$/yr**
Annual Electricity cost*	**$**	**24**	**$/yr**
Annual manpower cost *	**$**	**800**	**$/yr**
Annual cleaning cost	**$**	**200**	**$/yr**
Annual wastewater cost *	**None needed**		**$/yr**
Annual Waste permitting cost	**None needed**		**$/yr**
Annual safety training	**None needed**		**$/yr**
TOTAL VNX SYSTEM OPERATING COST $/YR		$2,898.73	$/yr
OPERATING COST SAVINGS USING VNX			$6,715
% SAVINGS USING VNX			70%

EDI

CONTINUOUS EDI VS MBDI

Case story #2 - Medium Flow System

System Details:

- **300 gpm (68.3 m3/h)**
- **11 µS/cm feed water**
- **24/7 operation**
- **2 x 60” dia MBDI**
- **1 x 6 VNX system**

MBDI: Mixed Bed De-Ionization

VNX®: Continuous EDI

MBDI SYSTEM OPERATING COST SUMMARY			
Replacement Resin cost	$	26,301	$
Chemical cost per regen	$	144	$/regen
Wastewater cost per regen	$	37	$/regen
Annual manpower cost *	**$**	**8,971**	**$/yr**
Annual resin cost *	**$**	**5,260**	**$/yr**
Annual chemical cost *	**$**	**10,363**	**$/yr**
Annual wastewater cost *	**$**	**2,665**	**$/yr**
Annual Waste permitting cost	**Not included**		
Annual safety training	**Not included**		
* Calculated			
TOTAL MBDI SYSTEM OPERATING COST $/YR		$27,258	$/yr

VNX SYSTEM OPERATING COST SUMMARY			
Electricity Cost per VNX module per day	$	0.07	$/day
Electricity Cost per VNX Skid	$	0.39	$/day/skid
Chemical cost per clean	$	100	$/clean
Wastewater cost per regen	None		$/regen
Annual module cost per skid*	**$**	**11,250**	**$/yr**
Annual Electricity cost*	**$**	**142**	**$/yr**
Annual manpower cost *	**$**	**800**	**$/yr**
Annual cleaning cost	**$**	**200**	**$/yr**
Annual wastewater cost *	**None needed**		**$/yr**
Annual Waste permitting cost	**None needed**		**$/yr**
Annual safety training	**None needed**		**$/yr**
TOTAL VNX SYSTEM OPERATING COST $/YR		$12,392.35	$/yr
OPERATING COST SAVINGS USING VNX			$14,866
% SAVINGS USING VNX			55%

EDI

CONTINUOUS EDI VS MBDI

Case story #3 - Large Flow System

System Details:

- **1000 gpm (227.12 m^3/h)**
- **11 µS/cm feed water**
- **24/7 operation**
- **2 x 114" dia MBDI**
- **4 x 5 VNX system**

MBDI: Mixed Bed De-Ionization

VNX®: Continuous EDI

NOTE: If the feed water is >11µS/cm, the operating cost saving by using VNX is even higher

MBDI SYSTEM OPERATING COST SUMMARY			
Replacement Resin cost	$	95,426	$
Chemical cost per regen	$	524	$/regen
Wastewater cost per regen	$	135	$/regen
Annual manpower cost *	**$**	**8,241**	**$/yr**
Annual resin cost *	**$**	**19,085**	**$/yr**
Annual chemical cost *	**$**	**34,542**	**$/yr**
Annual wastewater cost *	**$**	**8,882**	**$/yr**
Annual Waste permitting cost	**Not included**		
Annual safety training	**Not included**		
* Calculated			
TOTAL MBDI SYSTEM OPERATING COST $/YR		$70,751	$/yr

VNX SYSTEM OPERATING COST SUMMARY			
Electricity Cost per VNX module per day	$	0.07	$/day
Electricity Cost per VNX Skid	$	1.30	$/day/skid
Chemical cost per clean	$	400	$/clean
Wastewater cost per regen	None		$/regen
Annual module cost per skid*	**$**	**42,857**	**$/yr**
Annual Electricity cost*	**$**	**475**	**$/yr**
Annual manpower cost *	**$**	**400**	**$/yr**
Annual cleaning cost	**$**	**400**	**$/yr**
Annual wastewater cost *	**None needed**		**$/yr**
Annual Waste permitting cost	**None needed**		**$/yr**
Annual safety training	**None needed**		**$/yr**
TOTAL VNX SYSTEM OPERATING COST $/YR		$44,131.64	$/yr
OPERATING COST SAVINGS USING VNX / YR			$26,619
% SAVINGS USING VNX			38%

EDI

CONTINUOUS EDI VS MBDI

Operating Cost Comparison

Customer Quote:

"Purchase price is important but not the #1. The cost to operate the system is just as important, since I have to live with those costs year after year"

- **The cost of operating a chemical regenerated MBDI is increasing every year based upon the acid/caustic costs**
- **The cost of operating a CEDI system is electricity and cleaning chemicals (CIP on a quarterly basis)**
- **The typical amount of power needed to operate a CEDI system is one half of an RO booster pump**

EDI

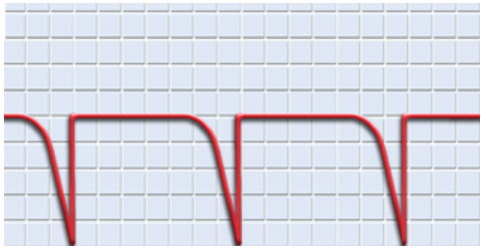
CONTINUOUS EDI VS MBDI

Operating Cost Comparison

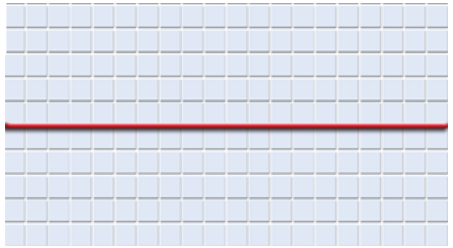
Customer Quote:

"The system must meet my water specification and production requirements"

- **CEDI can meet the same quality as MBDI product water with no break.**
- **Bad regenerations or loss of high purity resin layer in MBDI results in leakage and short vessel run lengths.**
- **Specialized CEDI modules can surpass MBDI in terms of boron and silica removal. (These modules are typically used in supercritical boilers or Microelectronics.)**
- **Constant, stable, predictable CEDI system product quality**
- **Constant, stable, predictable production; no spikes or "unexpected" breaks**



MBDI is a batch operation with potential breaks



CEDI delivers constant and consistent product water quality

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CONTINUOUS EDI VS MBDI

Space and Safety Savings

When estimating the "cost of owning", don't forget the other associated costs.

Space savings:

- **CEDI systems require less floor space when comparing just the MBDI vessels.**

m^3/h	MBDI	CEDI	saving
11	4.2 m^2	1.4 m^2	67%
68	15.8 m^2	7 m^2	56%
227	31.6 m^2	13.9 m^2	56%
681	267.9 m^2	62.7 m^2	77%

100 m^3/h skid

Safety:

- **The plant is inherently safer, without the need for bulk acid/caustic storage.**
- **Don't forget the soft costs, such as safety showers, containment equipment and other costs associated with chemical storage.**

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CONTINUOUS EDI VS MBDI

Conclusion

- Little operation cost
  - Require little energy
  - Continuous operation results in lower labor costs
  - Does not require hazardous chemical as MBDI does
- Smaller footprint than MBDI
  - Require less facilities in comparison to MBDI
- CEDI as a polisher after RO
- Consistent quality of produced water
- RO+CEDI can be the economically preferred choice, environmentally friendly and safe.

A quantum leap over traditional water treatment technologies

THANK YOU

Ruşen Eşref YAZGAN

www.farmafarm.com