Crane Environmental, Inc.

Western Region Boiler Association Conference

Jantzen Beach, OR

March 12, 2013

Crane Water University

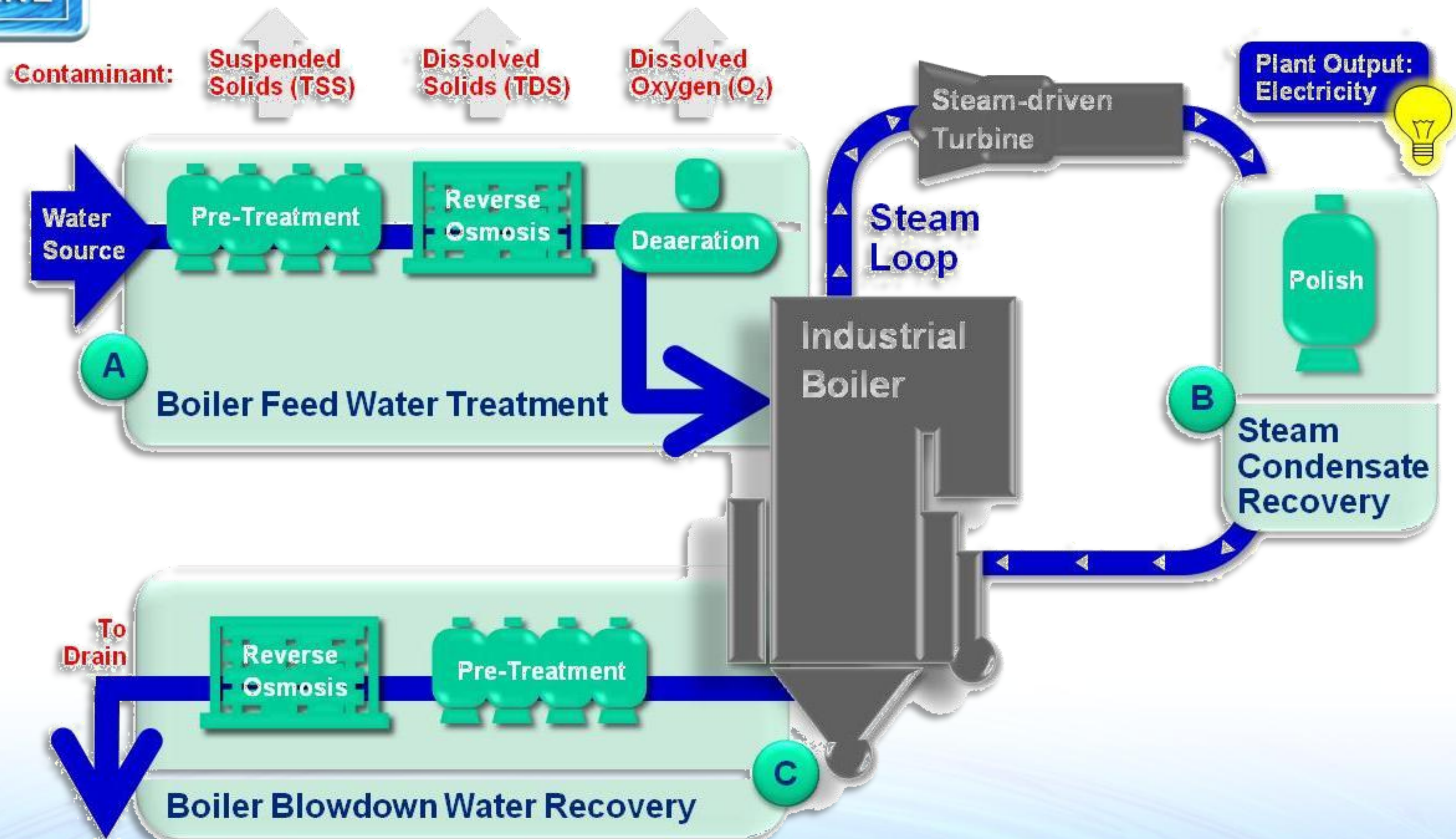
Basic Water Treatment for Power Engineering

Crane Water University Modules

Basic Water Treatment for Power Engineering

- Water Sources
- Basic Water Chemistry
- Common Impurities & Countermeasures
- Water Treatment Technologies Overview
- Basic Reverse Osmosis (RO)
- RO System Design
- Deaeration (DA)
- Boiler Feedwater Treatment
- Cooling Tower Feedwater and Blowdown Water Treatment
- Crane Environmental (CE) Capabilities

The Steam Loop



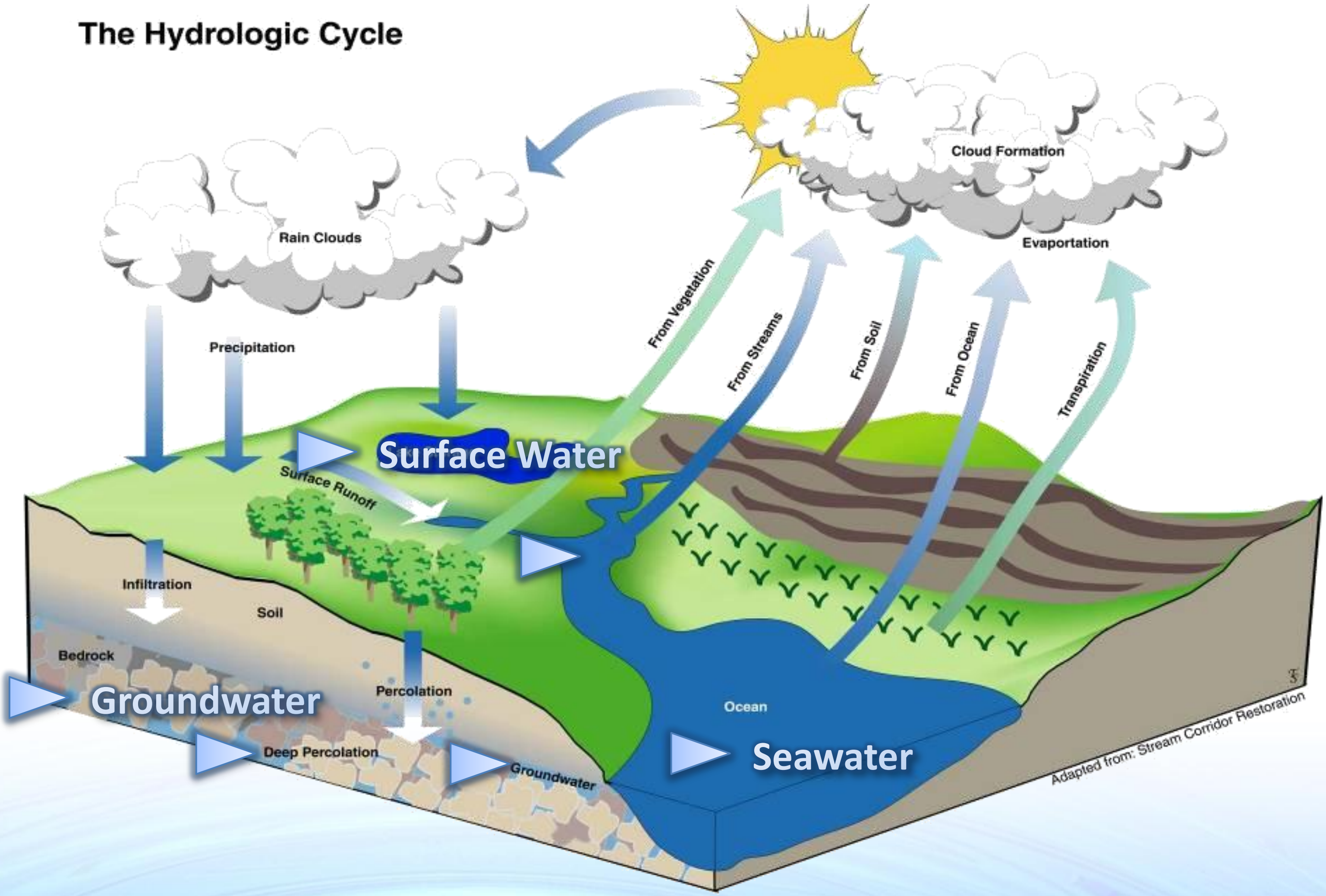
Natural Water Sources

Primary Sources:

- Surface Water: Lakes, Ponds, Rivers, Canals
- Ground Water: Wells, Springs
- Seawater: Ocean Intakes

Other Sources:

- Municipal: Town, City, County
- Brackish: Salt Water Intrusion
- Process Water



Typical Water Contaminants

Surface

- Typically high in suspended solids & sediment; Low in TDS (< 1000 mg/l)
- Likely to contain organic matter from fallen leaves, aquatic life, etc.
- Highly variable season to season

Ground

- Typically Low in suspended solids & sediment
- Can be high in TDS (>1000 mg/l)
- Likely to contain iron, sulfur, high levels of hardness (region dependent)

Municipal

- Usually has been treated to remove sediment and iron
- May be high in hardness and TDS usually < 500 mg/l
- Most likely will contain chlorine to control biological growth

Brackish & Ocean

- Very high in dissolved solids (TDS from 10,000-40,000 mg/l)
- Mostly sodium and chloride
- Likely to contain organic matter

Why is Some Knowledge of Water Chemistry Very Important?

- In order to solve a water need, you first must know what contaminants are present in your supply – ***Get Complete Feed Water Analysis!!!***

- What levels of these contaminants are required in the treated product? – ***Process Water Spec? / Concentrations Limits?***

- Understand how the contaminants are measured – ***TDS:*** *PPM / mg/l* ***Conductivity:*** *µmhos / µS,* ***Resistivity:*** *Megohms;* ***TSS:*** *NTU / SDI*

- Understand how to treat the water to remove specific groups of impurities – ***Pre-Treat / R.O. / Post-Treat…***

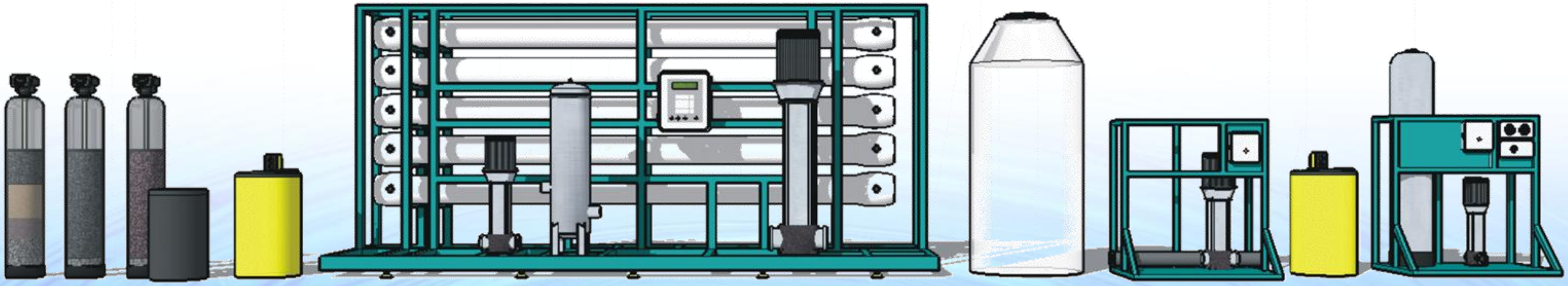
The Water Train

Industial Water Trains

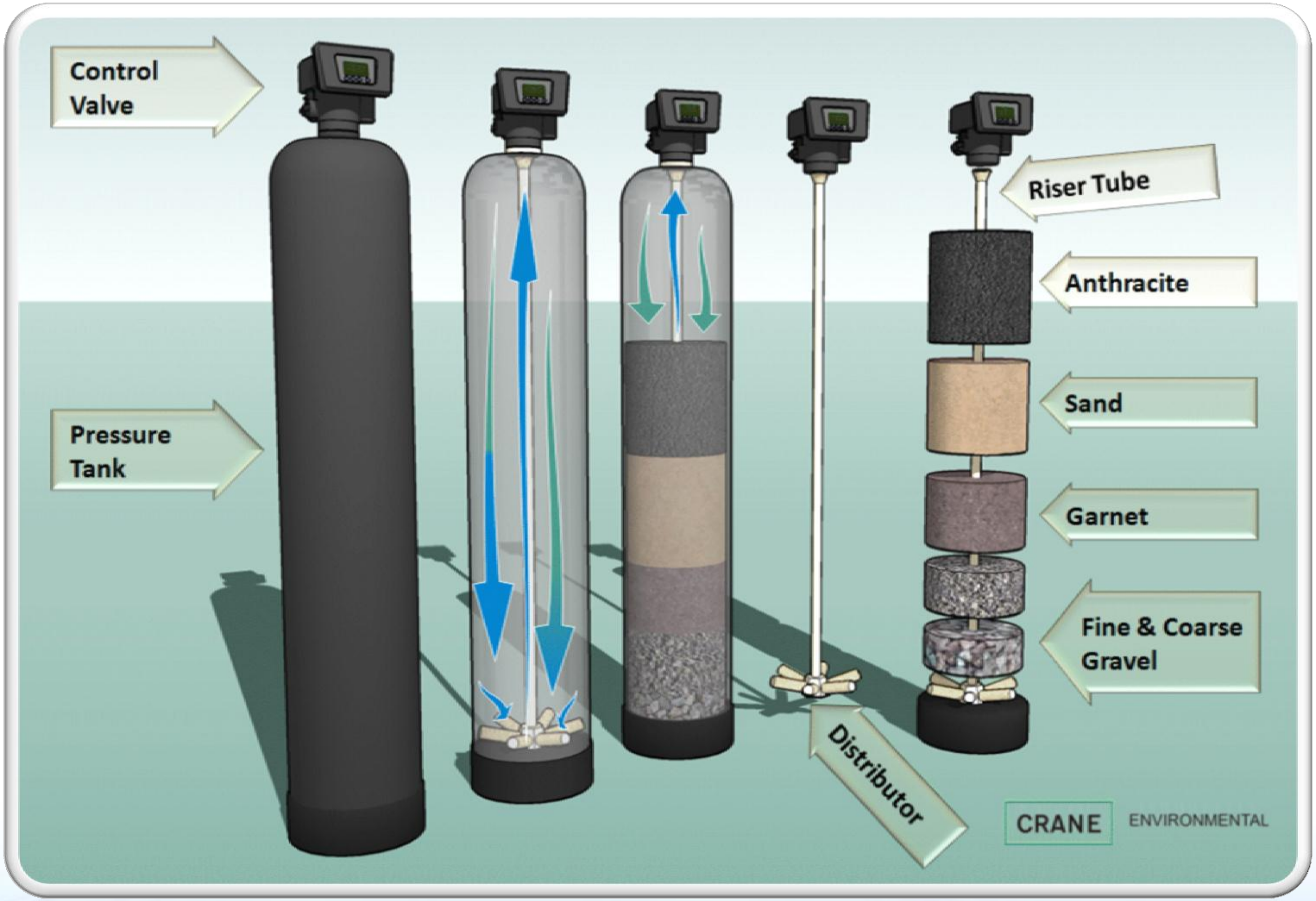
- A water treatment train is a collection of individual water treatment technologies working as a system to remove contaminants and condition water to meet specific downstream requirements

- The selection of specific components is driven by the characteristics of the incoming feed water against capital equipment and operational costs, size constraints, chemical usage, etc.

- The “ideal” configuration (technology + position in the train) is specific to each application and frequently each site



Multi-Media Filtration (depth filters)



Multi-Media Filtration (depth filters)

- Contains several layers of various density gravel, garnet, sand & anthracite
- Used for sediment removal (TSS) and large solids removal
- Requires backwashing
- Effectiveness increases over time
- Does not reduce total dissolved solids (TDS)



Multi-Media (continued)

- Multi-media filtration has various media layers that trap large particles, and successively smaller particles are trapped in the fine, upper layer of media over time.
- The result is a highly efficient filtering mechanism since removal can take place throughout the entire bed
- Multi-Media filters typically remove particles 10 – 15 microns in size or larger
- Automatic backwashing steps remove the contaminants trapped within the filter bed and washes them down the drain

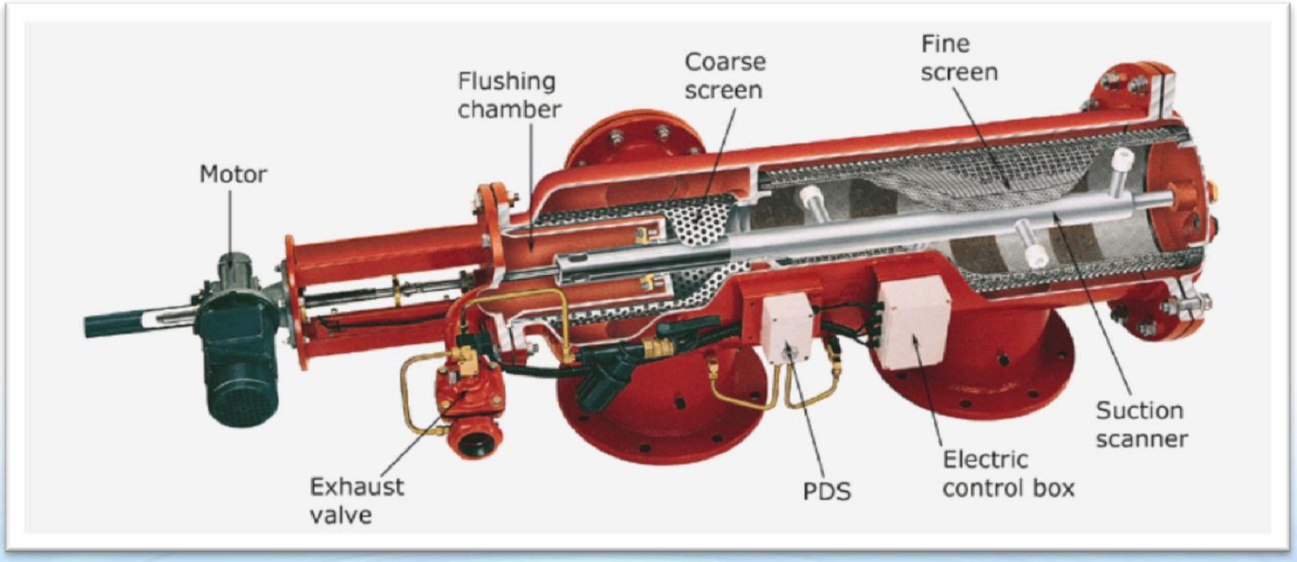
Multi-Media (continued)

- Modular design
- Fast, inexpensive installation
- Minimum energy requirements
- Optional PLC Controls
- Backwash based on differential pressure, time or throughput
- Stand Alone or Skid-Mounted

Multi-Media Filtration Alternatives

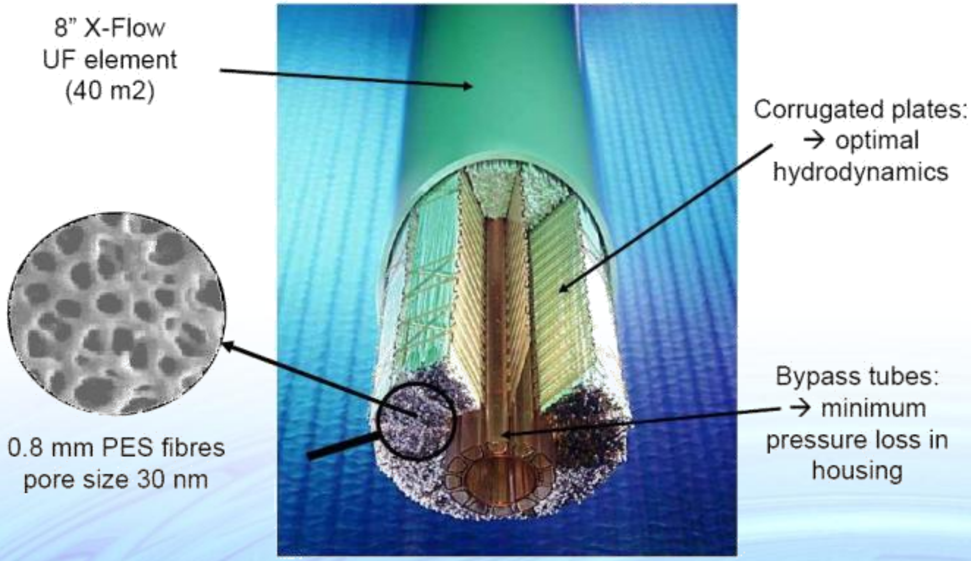
Screen Filters

- Ideal for very high levels of suspended solids
- Small footprint
- Variety of screen sizes (15 to 500+ micron)
- Rapid backwash (~30 seconds)
- Steel or composite construction



Ultrafiltration (UF)

- Ideal for high levels of suspended solids
- Filtration of suspended solids to 0.2 microns
- Backwash based on pressure drop
- 95% recovery
- Chlorine-tolerant



Iron Removal Media Filters

Why Remove Iron?

- Iron easily falls out of solution and sticks to surfaces (coagulant)
- Coats plumbing, valves, equipment, boiler tubes, etc.
- Stains surfaces
- Fouls RO membranes and plugs filters

Iron Removal Media Filters

Birm / KDF® Filters

- Iron removal
- H_2S removal (rotten egg smell)
- Heavy metals removal
- May require pre-chlorination to oxidize high iron levels

Manganese Greensand Filters

- Iron removal
- H_2S removal
- Media regenerated with potassium permanganate
- Potassium permanganate feeder or continuously dosed
- Greensand Plus® does not require regeneration ($KmNO_4$)

Activated Carbon Filters

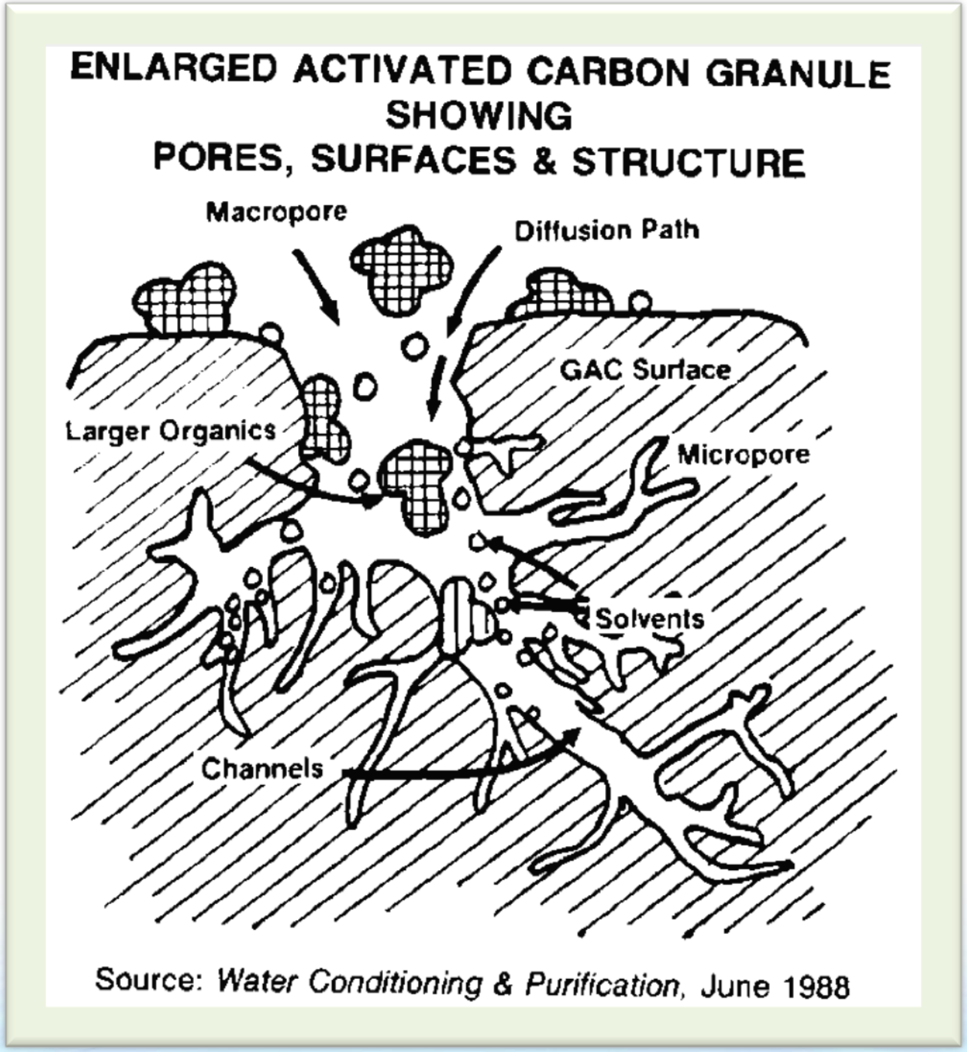
Advantages

- Effective de-chlorination
- No chemicals required
- Low mechanical maintenance

Disadvantages

- Not always the best choice for organics removal
- Supports bacteria growth
- Difficult to sanitize chemically
- Sheds particles – *backwash as infrequently as possible*

Granulated Activated Carbon (GAC)



Water Softeners (Ion Exchange)

Single Softener System

Twin Alternating Softener System

Ion Exchange (Softening)

- When many compounds *dissolve* in water they break up into their component parts, which are *charged particles*
- These particles are *atoms* or *groups of atoms* called *ions*
- Ions can be *positively charged* or *negatively charged*
- *Positive* charged ions are called *cations*: Sodium, Calcium and Magnesium
- *Negative* charged ions are call *anions:* Chloride, Sulfate, and Bicarbonate
- Molecules having one extra electron are called *monovalent* ions, those having two extra electrons are called *divalent* ions

Ion Exchange (Softening)

- Softening (reduces hardness)
- Hardness: Water that produces a scale forming & lather inhibiting tendency
- Utilizes resin to exchange undesirable dissolved ion for acceptable replacement ion
- Cation (softening) or anion removal
- Requires regeneration to restore effectiveness of resin
- Time between regenerations dependent on influent ion concentration

Ion Exchange (softening)

- Exchanges Ca++ (Calcium) and Mg++ (Magnesium) ions with Na+ (Sodium)
- ***Softening <u>does not</u> reduce TDS***
- Regenerates with salt brine solution (NaCl)
- Brine disposal restricted in some areas
- Different types of resin available: Cation, anion, mixed bed…
- In high flow applications, regeneration costs (for salt) may be prohibitive

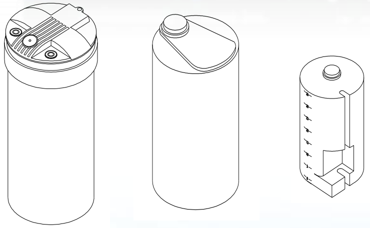
Water Softeners

- Multiple types (resins designed for specific applications)
- Modular design
- Optional skid-mounted packages
- Low maintenance
- Easy to install
- FRP or steel tanks
- PLC control options

Chemical Dosing

Usually Consists of:

- Chemical solution tank
- Dosing pump (metering)
- Static mixer (may be required)
- Retention tank (may be required)

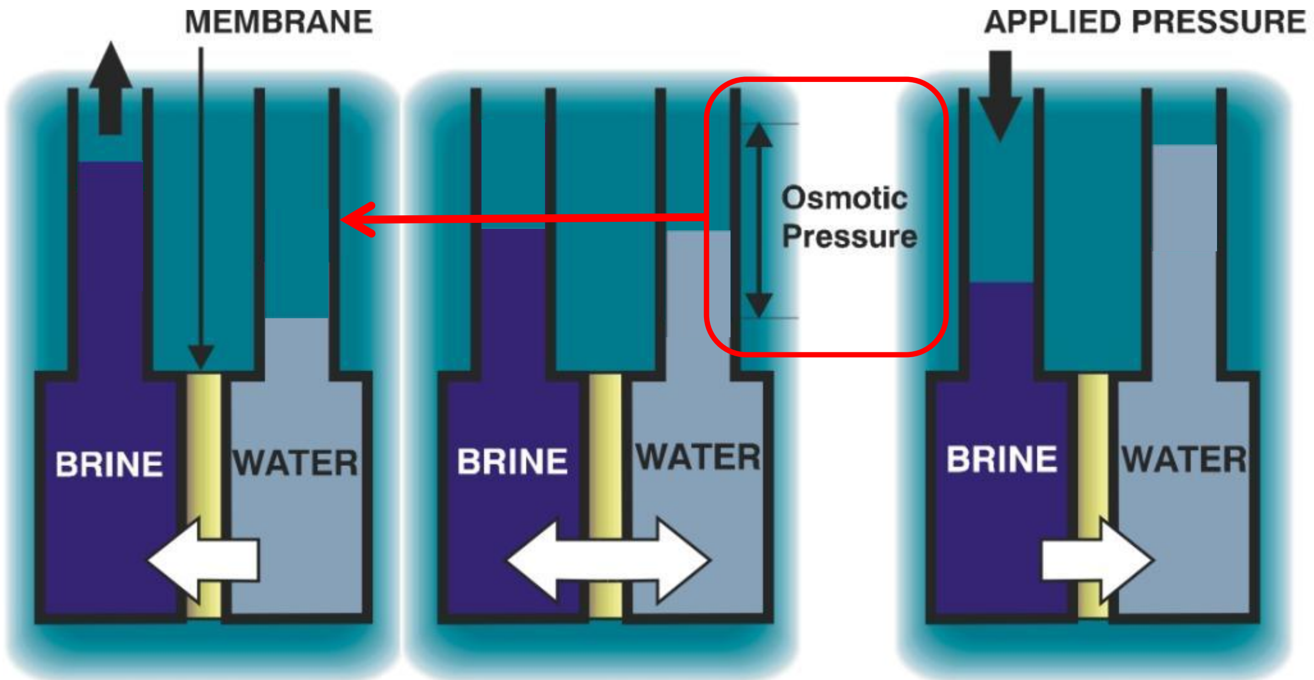


Chemical Dosing

Types:

- **Anti-Scalant** - Dispersant that prevents scale build-up on membranes; Alternative to water softening; *More cost effective than softening on industrial applications*
- **Acid** – Lowers pH
- **Caustic** – Elevates pH (usually NaOH)
- **Chlorine/Biocide** – To destroy organics
- **Sodium Metabisulfite** – Chlorine removal; Alternative to carbon filtration; *More cost effective than carbon filter on industrial applications*

Reverse Osmosis Fundamentals



OSMOSIS

Water flows from low concentration of salts to higher concentration.

EQUILIBRIUM

Osmotic Pressure is the pressure required to stop water flow and reach equilibrium.

REVERSE OSMOSIS

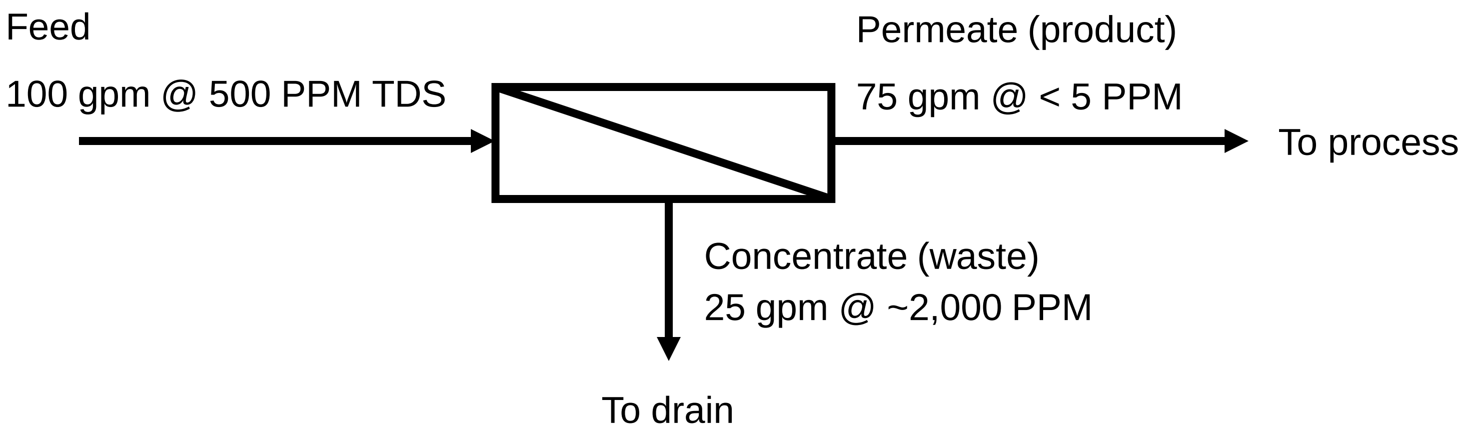
By applying pressure greater than Osmotic Pressure, flow of water is reversed; water flows from higher concentration solution to lower.

$\pi_1 < \pi_2$

$P = \Delta\pi$

$P > \Delta\pi$

Reverse Osmosis Terms



Feed (gpm) = Permeate (gpm) + concentrate (gpm)

Rejection = % of salts (TDS) that do not pass through membrane

Typically 99%

Recovery = % of feed flow that passes through membrane (permeate)

Maximum is typically 75 to 80%

Reverse Osmosis Terms

% Recovery

- The *ratio* of the *permeate flow* to the *feed flow*, usually expressed as a percentage

$$\% \text{ Recovery} = \left[\frac{\text{Permeate Flow}}{\text{Feed Flow}} \right] \times 100$$

% Rejection

- The percentage of *feed water TDS* that *does not pass through* the membrane

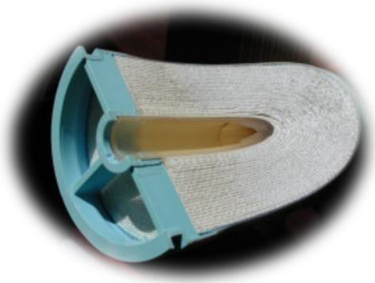
$$\% \text{ Rejection} = \left[1 - \frac{\text{Permeate TDS}}{\text{Feed TDS}} \right] \times 100$$

Flux

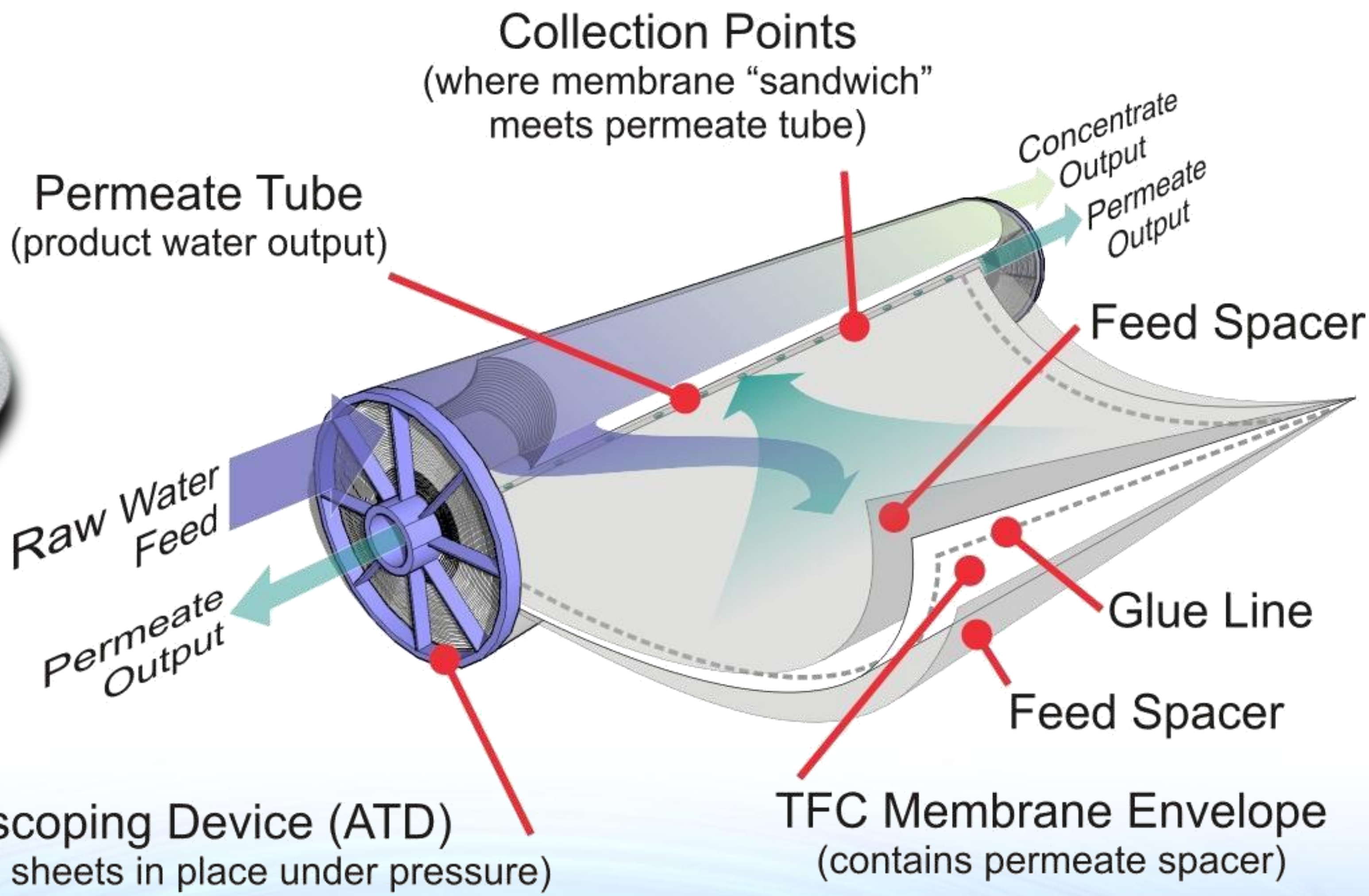
- Unit flow of water through a unit area of membrane per unit of time
- The most common units of measure are *GFD* (Gallons / Square Foot - Day)
- The higher the flux, the faster membranes will foul which decreases system performance

$$\text{Flux (gfd)} = \frac{\text{Permeate Flow (gpd)}}{\text{Membrane Area (ft}^2\text{)}}$$

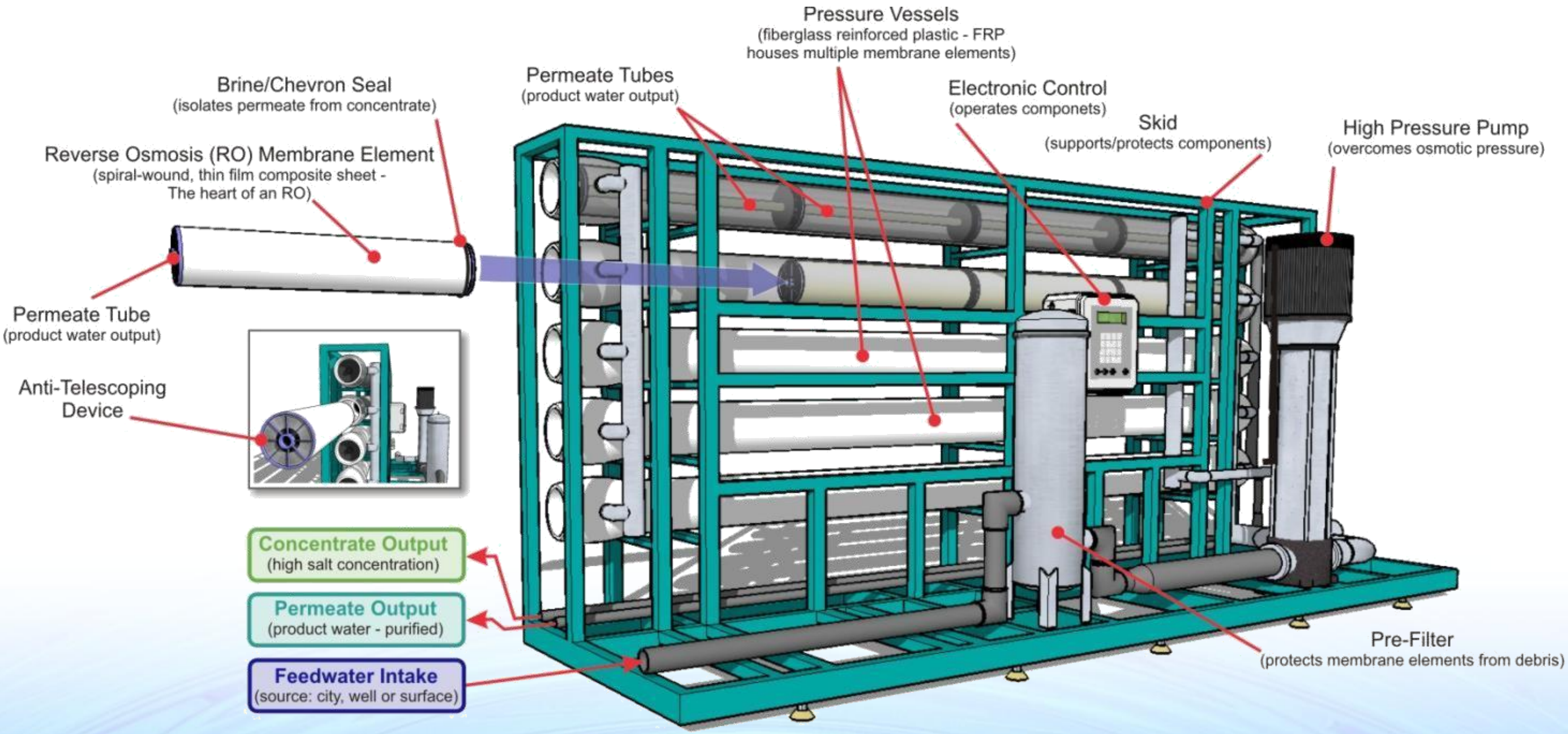
Spiral Wound RO Elements



(cutaway)



Anatomy of an RO System



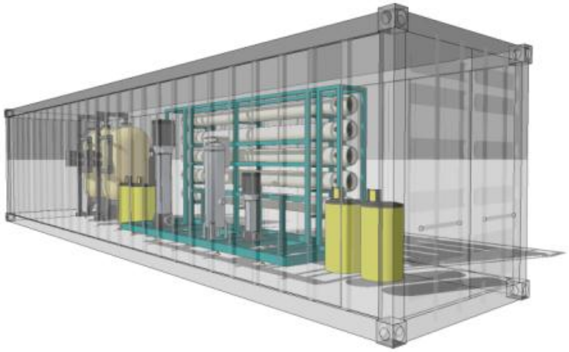
CE RO-Centric Design (continued)

- All systems designed for 3rd year of membrane life
- >40 PSI feed water pressure required *at entrance of RO skid* (be sure to account for pressure drops through pre-treatment tanks)
- Design for local electrical power supply (voltage/frequency/phase)
- Comply with membrane manufacturer's recommendations for:
  - Flux
  - Min/Max concentrate flow
  - Min/Max feed flow
  - Operating pressures

CE RO-Centric Design (continued)

Common Optional Features

- High TDS alarm / divert
- ORP meter to monitor / prevent chlorine damage
- Clean-In-Place (CIP) or cleaning station (CLS)
- Remote monitoring/controlling
- Fully containerized systems
- Chemical dosing monitoring/controlling



CE RO-Centric Design: Post Treatment

- Permeate Storage Tanks – level controls, bulkhead fittings
- U/V Sterilization Lights – To destroy organic and biological material
- Ozone Generation Systems – Purification; eliminates the need to use chlorine; widely used at bottled water plants
- pH Adjustment – Elevate or lower permeate pH through chemical dosing, calcite filters, etc.
- Chemical Dosing – chlorination, pH adjustment
- Pump Skids – Feed water, booster pumps, delivery pumps, etc.

Double / Triple Pass RO Systems

- System design links 2 to 3 RO systems in series
- May be integrated in single or multiple skid designs
- Used in applications requiring high purity water as in high pressure boilers
- Produces ultrapure water with < 1ppm (TDS) without the need for traditional DI tanks
- Does not require additional chemicals or regeneration
- Most economical (equipment & operational costs) means to produce ultrapure water
- DPRO™ and TPRO™ systems utilize concentrate recycle to achieve the same overall recovery as single-pass RO's

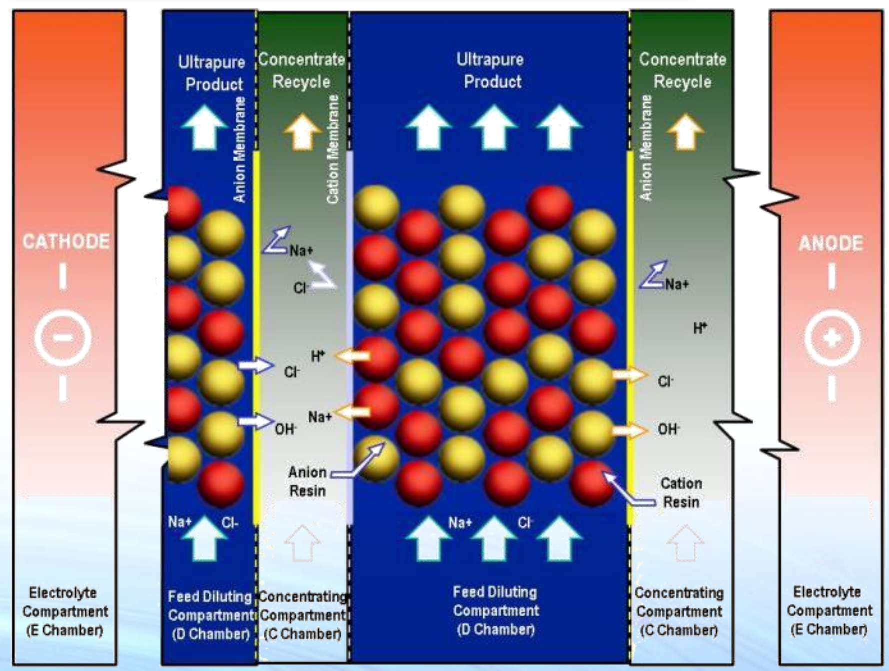
Deionization (DI)

- Utilizes specially-engineered ion exchange resin to remove additional dissolved solids (cation / anion)
- Can be separate bed or mixed bed design
- Requires regeneration with strong caustic and acid solutions
- Waste from regeneration must be neutralized before disposal
- Regeneration is either performed in situ or through tank exchange programs
- Labor-intensive and high servicing costs

CE RO-Centric Design: Ultra-Pure Applications

Electrodeionization (EDI)

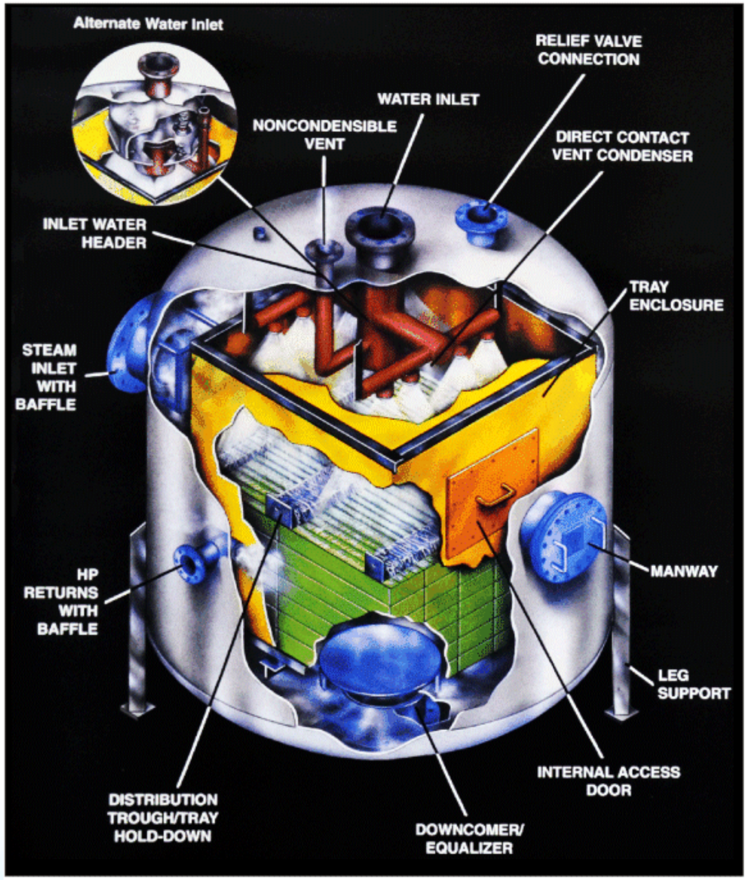
- Incorporate membrane / resin hybrid design using high voltage DC current as the driving force to reduce TDS to ultrapure levels
- Ions removed continuously
- No regeneration chemicals
- Mixed bed resins for best silica removal
- Continuous flow of up to 18 meg-ohm water



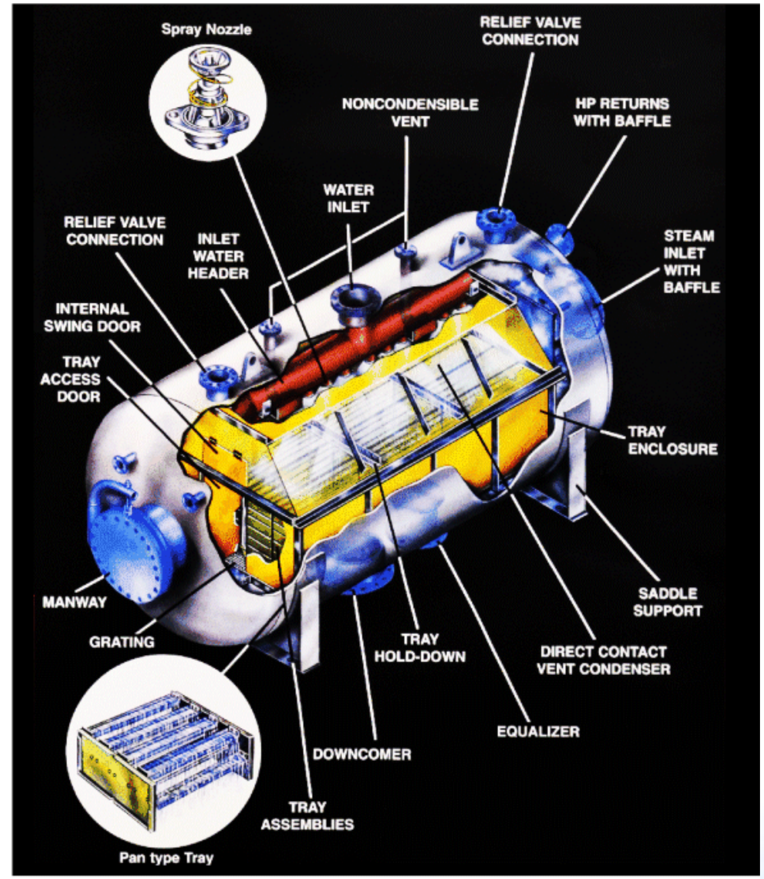
Deaeration and Boiler Operation & Maintenance

- Commercial and Industrial Boilers operate at their best when the incoming boiler feed water is free from dissolved gasses
- Dissolved oxygen will cause severe corrosive damage to the boiler internals
- Dissolved oxygen also combines with any dissolved carbon dioxide to form carbonic acid which accelerates corrosion
- Deaerators are designed to remove oxygen down to 7 parts per billion (ppb) by weight (0.0005 cm^3/L) or less
- A properly operated and well maintained deaerator will dramatically improve boiler lifespan and performance as well as reduce the volume of chemical oxygen scavenger required, such as sodium sulfite (Na_2SO_3)

Cochrane Counterflow Spray-Tray Deaerators

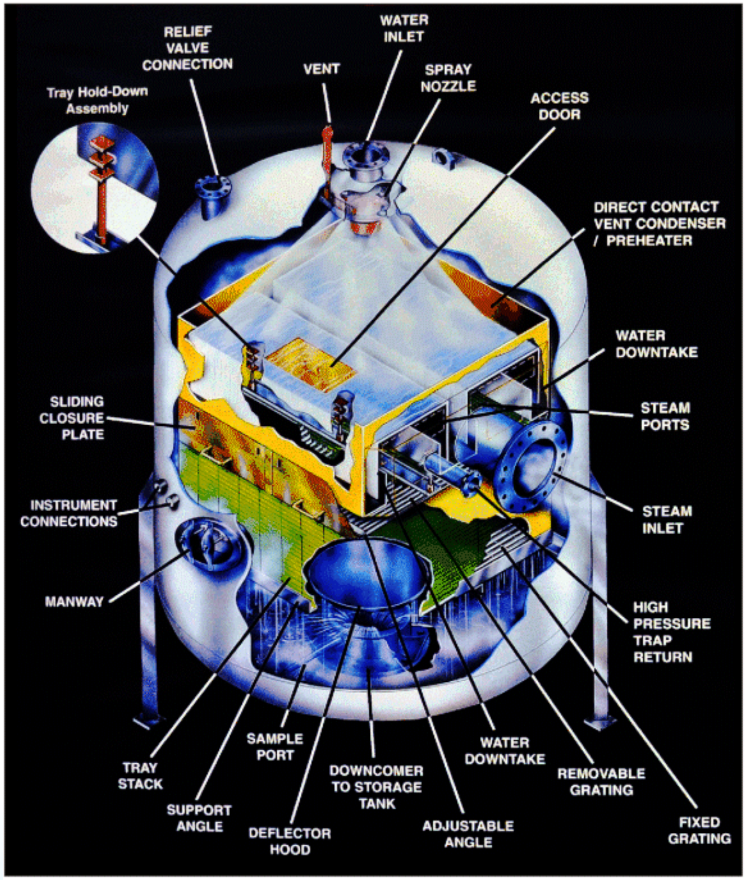


Vertical Configuration

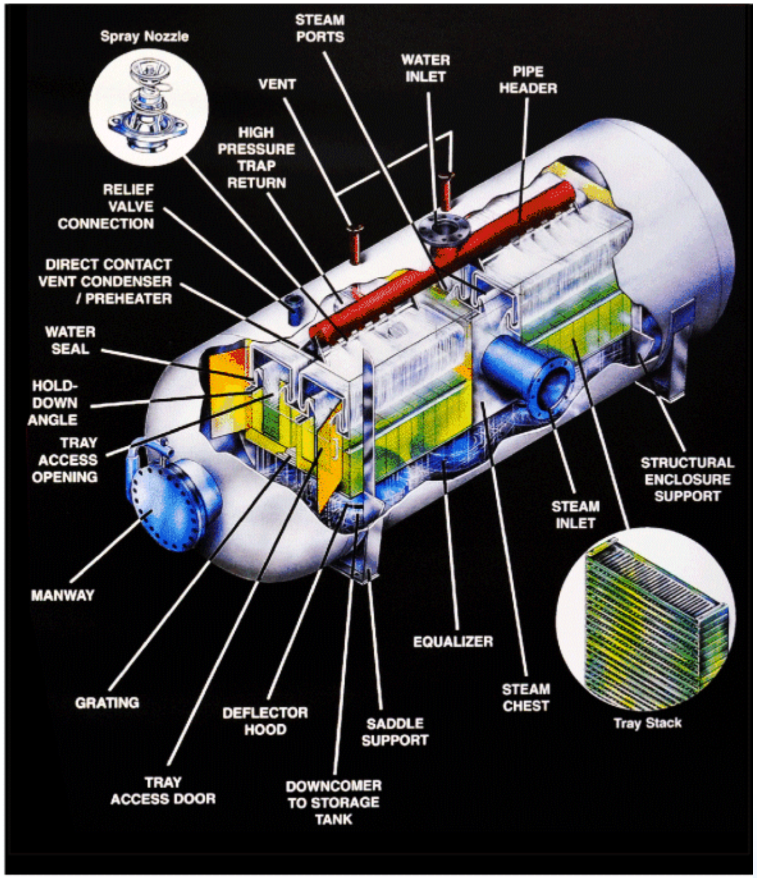


Horizontal Configuration

Cochrane Parallel Downflow Spray-Tray Deaerators



Vertical Configuration



Horizontal Configuration

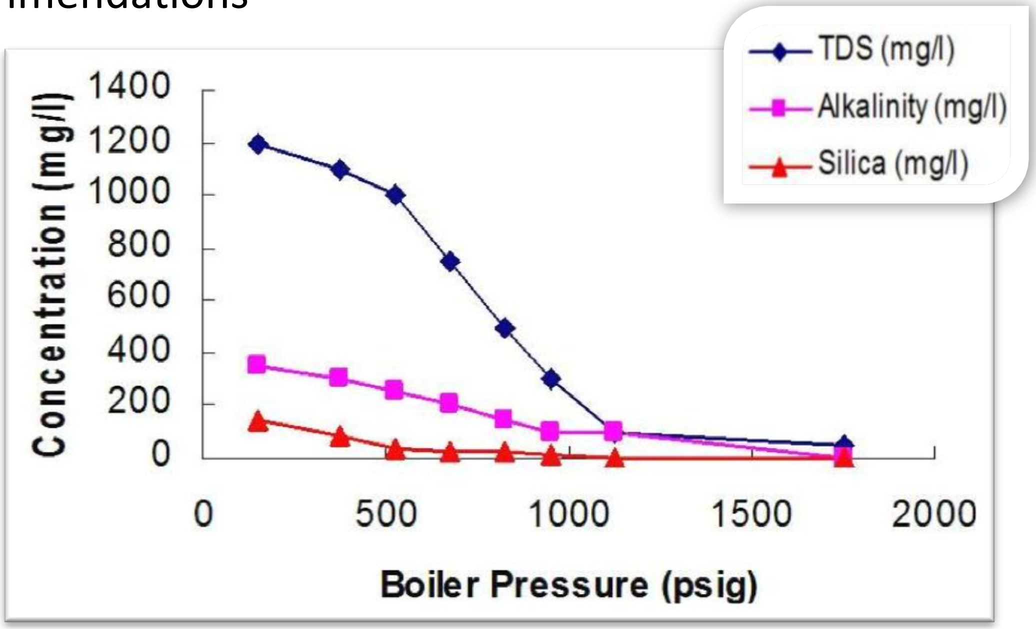
Why treat boiler feed water?

- Source water contains sediment and dissolved solids
- When this water is *evaporated (or boiled),* water leaves the system as vapor, *but the sediment and dissolved solids are left behind* in a lesser amount of water
- The result: the original dissolved solids and sediment are present at a higher *concentration*
- As the concentration of a dissolved solid *increases*, its tendency to *precipitate* (form a solid) from solution increases

Why treat boiler feed water?

- As the dissolved solids concentrate and begin to precipitate, they form scale on any available surface, i.e. heating surfaces in the boiler drum
- This scale acts as an inhibitor to heat transfer and the boiler will begin to operate below capacity and may eventually fail
- The concentration at which a dissolved solid will scale decreases as pressure increases; this indicates an increasing purity requirement with increasing boiler pressure
- *Greatly reduce Blowdown*

ABMA Boiler Drum Water Recommendations



Post R.O. Blowdown Calculation

Assumptions:

Average Steam Production = 300,000 pounds/hr
Steam Pressure = 600 psig
Chloride Concentration in Feed Water = 150 mg/l
Current Boiler Blowdown rate = $\boxed{12\%}$
Chloride Concentration in Feed Water treated by RO = 1 mg/l
Current Chloride Concentration in Drum = 1,000 mg/l
Desired Chloride Concentration in Drum = 200 mg/l
Boiler Efficiency = 82%
Energy Costs = $10 / million BTU
Average Makeup Water Temperature = 40 °F

$$\text{Current Boiler Feedwater Usage} = \frac{SteamOutput}{(1 - Blowdown)} = \frac{300{,}000\,pph}{1 - 0.12} = 340{,}909\,pph$$

$$\text{Boiler Blowdown Rate using RO} = \frac{C_{feed}}{C_{boiler}} = \frac{1mg/l}{200mg/l} = \boxed{0.5\%}$$

$$\text{Boiler Feedwater Usage using RO} = \frac{SteamOutput}{(1 - Blowdown)} = \frac{300{,}000\,pph}{1 - 0.005} = 301{,}508\,pph$$

$$\text{Makeup Water Savings} = 340{,}909 - 301{,}508 = \boxed{39{,}401\,pph}$$

$$\text{Thermal Energy Savings} = Enthalpy_{boilerwater} - Enthalpy_{feedwater} \approx 450BTU/lb$$

$$\text{Total Energy Savings} = \frac{39{,}401\,pph \times 450BTU/lb \times \$10/millionBTU}{0.82 \times 1{,}000{,}000} = \$216.22/hr$$

Annual Energy Savings = $\boxed{\$1.89\ \text{million}}$

Annual Water Savings = 41,385,000 gallons (cost per gallon should include pumping costs, chemical treatment costs and any usage fees)

Crane Total System Management

1. Initial Site Survey
2. Process/Equipment Selection
3. System Engineering & Design
4. Manufacture Equipment
5. Project Management
6. System Commissioning
7. After-Market Parts, Annual Service Contracts, Remote Monitoring

CRANE

Field & Technical Services

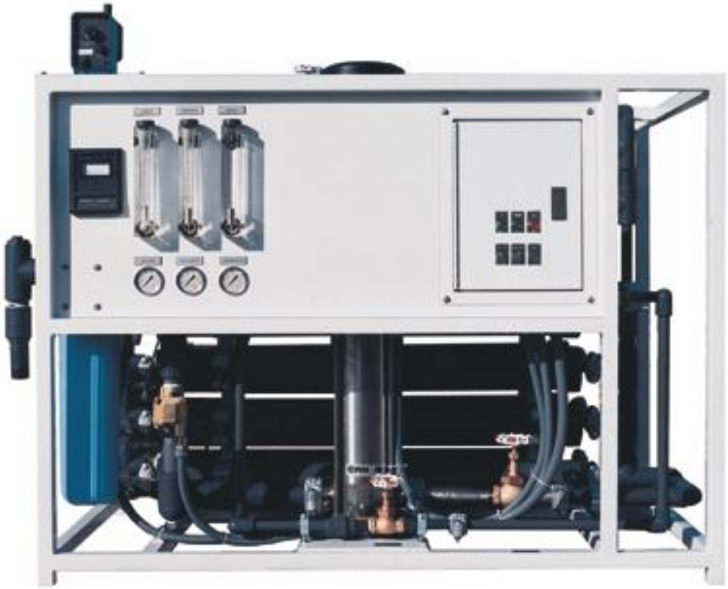
Complete product-line field service support – worldwide…

- Commissioning / startup services
- Yearly service contracts
- System maintenance (weekly/monthly)
- Emergency technical support – 24/7
- Remote monitoring / troubleshooting
- Ongoing operator training

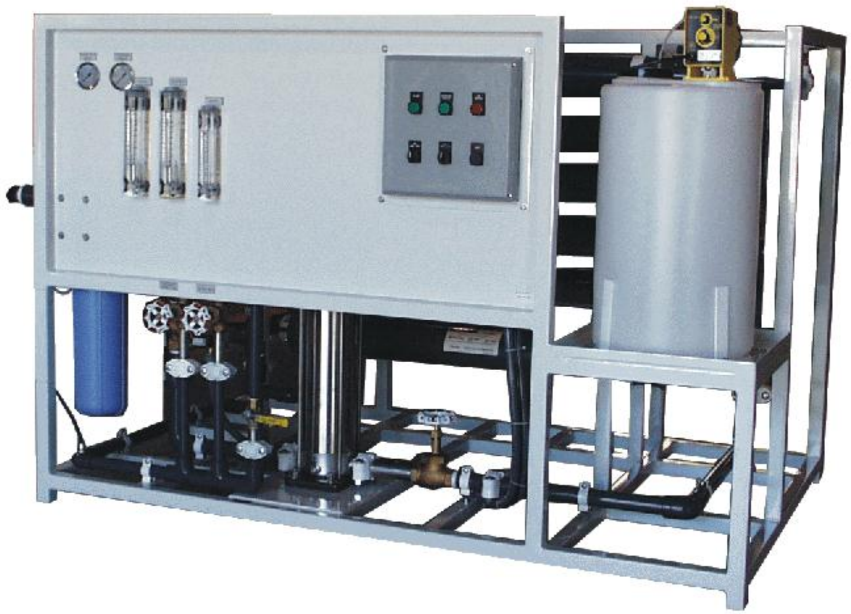




EPRO Medium RO's



21,500 GPD



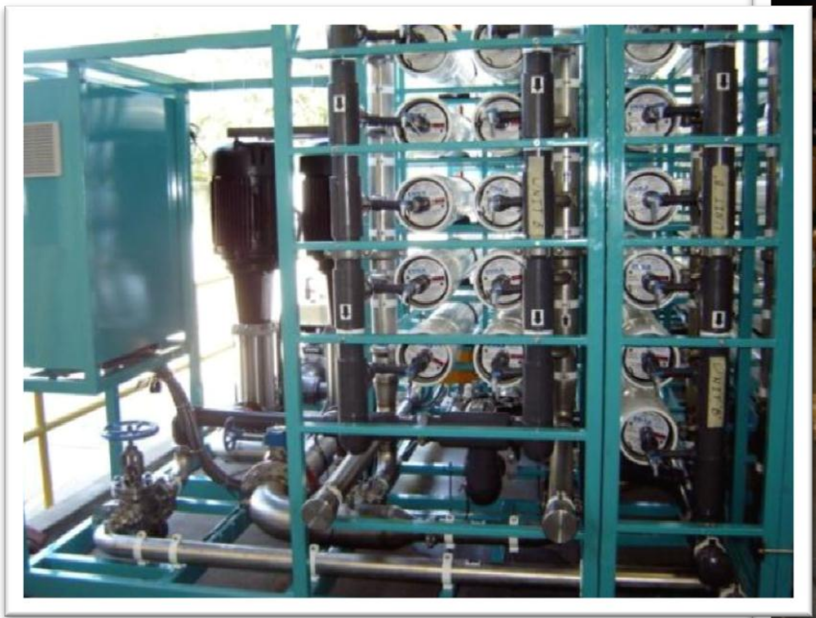
19,000 GPD

EPROi Large RO’s

28,800 GPD

216,000 GPD

EPROi Large RO's



720,000 GPD

(Modular RO)

EPROi SW Seawater RO's(17k – 40k+ ppm)

360,000 GPD

(From Seawater)

EPROi SW Seawater RO's(17k – 40k+ ppm)

20,000 GPD

(From Seawater

Skid-mounted

Pretreatment)

ERI PX System

(State of the art

energy recovery

Technology)

Pretreatment

Multimedia Filters

(Skid-mounted with Booster Pumps)

Pretreatment

Softeners

(Skid-mounted SS Twin Alt. 60x67" Tanks)

Pretreatment

Carbon Filters

(Skid-mounted FRP

Triplex 48x72” Tanks)

Multimedia Filters

(Skid-mounted FRP

Duplex 30x72” Tanks)

Post Treatment

Electrodeionization (EDI)

(Skid-mounted 25 GPM EDI

30 GPM RO)

Electrodeionization (EDI)

(Skid-mounted 100 GPM EDI)

Post Treatment

Deionization (DI)

(Skid-mounted 45 GPM Mixed Bed)

EPROi Containerized Systems

Questions?

For More Information

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