



# Commercial High-Purity Water Systems and Applications

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## Overview

- High-purity water: definitions
- High-purity water: methods
  - Distillation
  - Deionization
  - Membrane filtration (RO)
  - RO + Electro DI
- Commercial RO applications
- RO system components
- RO system sizing/selection



# High Purity Water



Conductivity	Resistivity
0.01 uS	100 MSΩ
0.05 uS	20 MSΩ
0.1 uS	10 MSΩ
1 uS	1 MSΩ
10 uS	0.1 MSΩ
100 uS	0.01 MSΩ
1 mS	1 kΩ

- “Water from which a significant portion of impurities have been removed” (typically 90% or more).
- “Impurities” = suspended solids, dissolved solids, microorganisms
- Levels of dissolved solids measured in units:
  - Ohms -cm of resistivity
  - Micromhos-cm/microsiemens of conductivity
  - PPM of TDS (total dissolved solids)
    - (varies by solids but is approximately = to micromhos X 0.67)

# Different Levels of High-Purity

- Typical tap water:
  - 100 – 450 ppm TDS
  - 6670 – 1490 ohms-cm resistivity
  - 150 – 670 micromhos-cm/microsiemens conductivity
- Humidification Systems (typical):
  - Approx 10 ppm TDS
  - 67,000 ohms-cm resistivity
  - 15 micromhos-cm/microsiemens conductivity



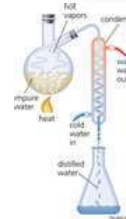
# Different Levels of High-Purity

- Clinical & Laboratory Standards Institute/ASTM:
  - CLSI Type III:
    - Res: 100,000 ohms, Cond: 10  $\mu$ S, TDS: approx 6.7 ppm
    - Typical for medical sterilization equipment
  - ASTM/CLSI Type II:
    - Res: 1,000,000 ohms, Cond: 1  $\mu$ S, TDS: approx 0.67 ppm
    - Typical for laboratory fixtures/equipment
  - ASTM Type I:
    - Res: 18,000,000 ohms, cond: 0.056  $\mu$ S, TDS: approx 0.038 ppm
    - Used for semiconductor manufacturing



## Method 1: Distillation

- Boil water, capture steam
- Very energy intensive!
- Often multiple passes

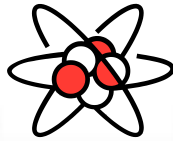


- Purity level for single pass distillation (typical):
- 6.7 ppm TDS:
  - 100,000 ohms resistivity
  - 10  $\mu$ S conductivity



## Method 2: Deionization

- Atoms and molecules with a positive or negative charge are called “ions.”
  - Cations = Positively charged ions
    - Ex: calcium, iron, magnesium, sodium, hydrogen, copper, aluminum, etc.
  - Anions = Negatively charged ions
    - Ex: silica, bicarbonates, tannins, chloride, fluoride, etc.



## Method 2: Deionization

- Water passes through cation (++) resin bed, cations removed,
  - exchanged for H<sup>+</sup> (hydrogen)
- Water passes through anion (--) resin bed, anions removed,
  - exchanged for OH<sup>-</sup> (hydroxide)
- $H + OH = H_2O$
  
- Media needs frequent regeneration
  - Hydrochloric acid for cation resin
  - Sodium hydroxide for anion resin
  - Usually done off-site
    - Frequent, Expensive exchange services!



## Method 2: Deionization

- Purity level for dual bed DI (typical):
  - 6.7 – 13.4 ppm approx TDS:
  - 100,000 – 50,000 ohms resistivity
  - 10 - 20  $\mu\text{S}$  conductivity
- Purity level for mixed bed DI (typical):
  - 0.067 (or less) ppm approx TDS:
  - 10,000,000 (or more) ohms resistivity
  - 0.1 (or less)  $\mu\text{S}$  conductivity
- Purity level for dual bed followed by mixed bed DI (typical):
  - 0.038 ppm TDS:
  - 18,000,000 ohms resistivity
  - 0.056  $\mu\text{S}$  conductivity

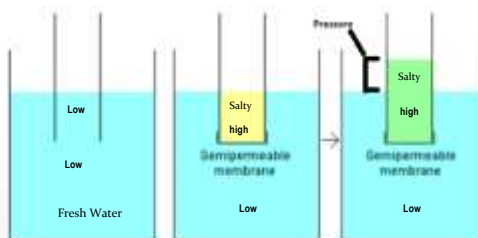
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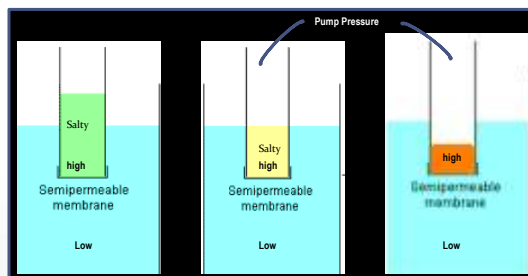
## Method 3: Membrane Filtration

- Definition: Osmosis
  - “movement of a solvent through a semipermeable membrane (as of a living cell) into a solution of higher solute concentration that tends to equalize the concentrations of solute on the two sides of the membrane.”
    - Actually creates “osmotic pressure”
    - Temperature-dependent



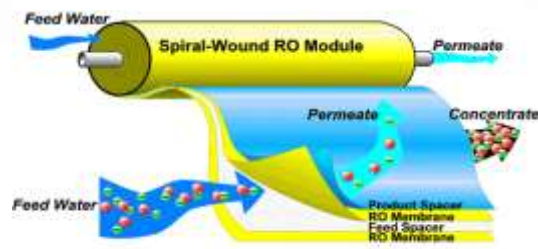
## Method 3: Membrane Filtration

- Definition: Reverse Osmosis
  - Overcoming (and reversing) osmotic pressure through a semi-permeable membrane, usually via a high-pressure pump. (typically 125-250 psi)
    - Some residential systems can work at 30 psi
    - Some desalinization systems work at 900+ psi



## Method 3: Membrane Filtration

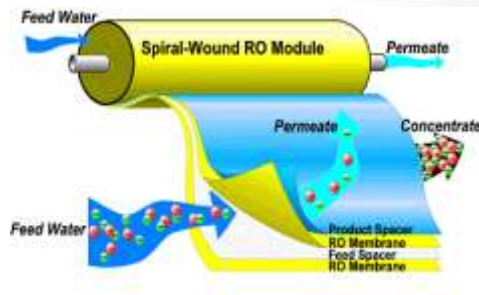
- Membranes: Spiral Wound TFC\* and CTA\*\*



- \* Definition: Crossflow Filtration
  - Instead of trapping impurities in the membrane, 2 exit streams are created:
    - 1) Permeate = purified water, which has passed through membrane
    - 2) Concentrate = wastewater (with concentrated impurities), which has NOT passed through membrane (anywhere from 0.25 to 6 X permeate volume generated!)
  - RESULT: MEMBRANE IS CONSTANTLY WASHED

## Method 3: Membrane Filtration

- Membranes: Spiral Wound TFC\* and CTA\*\*



- \*TFC = Thin Film Composite (developed by NASA) – MOST COMMON
  - made of polyamides (similar to wool, silk, nylon, etc.)
  - less bacteriological growth, higher production rates
  - sensitive to chlorine!
- \*\*CTA = Cellulose Triacetate (older technology)
  - made of cellulose (similar to rayon)
  - only advantage: chlorine tolerant

## Method 3: Membrane Filtration

- Typical commercial RO membranes:
  - NaCl rejection rates: 96% - 98.5%
  - Operating pressure 100 - 150 psi
  - Filtration down to 0.1 nm (0.1 billionth of a meter)
    - = 0.0001 micron
    - Also known as “hyperfiltration”
- Other membranes offer:
  - Higher rejection rates (up to 99%)
  - Lower energy consumption (less pressure required)
  - Ability to filter brackish water and seawater

## Method 3: Membrane Filtration

- Similar technologies with higher production rates:
  - Nanofiltration
    - NaCl rejection rates: 80%-90%
    - Filtration down to 1 nm (1 billionth of a meter)
      - = 0.001 micron
  - Ultrafiltration
    - Filtration down to 3 nm (3 billionths of a meter)
      - = 0.003 micron
  - Microfiltration
    - Filtration down to 50 nm (50 billionths of a meter)
      - = 0.05 micron

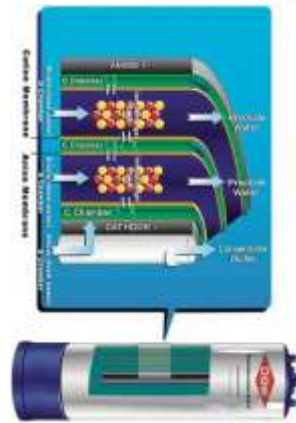
• **0.2 micron adequate to remove approx 99.9% of bacteria** •

## Method 4: Electrodionization (EDI)

- Always follows a Reverse Osmosis system
- Can be used to reach Type I (semi-conductor) quality
- Membrane technology + DI resin + electrical field
  - = virtually complete removal of all dissolved solids
  - = continuous regeneration of DI media
    - Electrical field breaks H<sub>2</sub>O into H<sup>+</sup> and OH<sup>-</sup> for constant media regeneration without chemicals
  - = continuously washed membrane (like RO)
- Sensitive to water quality!
- Knowledgeable maintenance staff required!



## Method 4: Electrodionization (EDI)



## High-Purity Water Systems

- Typical applications:
  - Sterilization equipment
  - Humidification systems
  - Steam boilers
  - Drinking water systems
  - Industrial process systems
  - Carwash rinse systems
  - Laboratories
  - ... and more



# Commercial RO System Components

- Reverse Osmosis Unit
  - Solenoid valve, pre-filters, high pressure pump(s), membranes, housings, flow meters, pressure gauges, controls, aluminum frame
  - 100 GPD – 200,000+ GPD available
  - Concentrate recycle option
  - Control/monitoring options
  - Float switch, pressure switch, or ultrasonic level controls
  - Dual pass for Type II water



# Commercial RO System Components

- Thermostatic Mixing Valve:
  - (Pre-RO unit)
  - RO units operating range: 40° - 105°
  - Typical temp: 77°F
    - At 50°: 42% production loss
    - At 61°: 27% production loss
    - At 86°: 16% production increase
  - Hot and cold water supplies required



# Commercial RO System Components

- Sediment Filter:
  - (Pre-RO unit)
  - Pre-screens suspended solids
  - Cartridge, bag, or backwashing
    - Psid gauges necessary for cartridge/bag filters!
  - Often included on RO system frame



# Commercial RO System Components

- Water Softener:
  - (Pre-RO unit)
  - Removes calcium, and iron (hardness) to protect membrane from fouling
  - Weak cation exchange media
    - Backwashes with saltwater
  - Sized to regenerate every 3 – 7 days, twin alternating system needed for 24 hour soft water



# Commercial RO System Components

- Carbon Filter:
  - (Pre-RO unit)
  - Granulated activated carbon
  - Destroys chlorine and chloramines (membrane protection)
  - Backwash every 3 days to remove trapped sediment
  - Media replacement every 3-5 years (typical)
  - Twin alternating system needed for 24 hour protection



# Commercial RO System Components

- Pre-Treat Injection System:
  - (Pre-RO unit)
  - Injects chemicals to protect membrane from silica over 1ppm, metal oxides, hardness
  - Can be used in place of ion exchange (water softener)
  - Often includes float switch for RO unit shutdown on empty chemical tank



# Commercial RO System Components

- DI Post-Polishing Filters:
  - (Post-RO unit)
  - Used to further purify water (down to Type II or III levels)
  - Replaceable cartridges
  - Fiberglass exchange tanks
  - Additional TDS monitoring



# Commercial RO System Components

- Storage Tank:
  - (Post-RO unit)
  - Atmospheric polyethylene tank (most applications)
    - 100 – 5000 gallons (typical)
    - Float switch or ultrasonic level
    - Overflow, drain valve, suction outlet, recirc return (optional)
  - Fiberglass, hydropneumatic tank (select applications)
    - 30 – 120 gallons (typical)
    - Pressure switch control



# Commercial RO System Components

- Delivery Pump(s):
  - (Post-RO unit)
  - Repressurize water for fixtures/equipment
  - 316 Stainless steel required!
  - Redundant pump recommended
  - Continuous operation, pressure switch, or VFD control



# Commercial RO System Components

- Ultraviolet Lamp(s):
  - (Post-RO unit)
  - Destroy any bacteria from tank
  - Eliminate need for costly / lengthy RO unit disinfection
  - Monitors available
  - Typically followed by 0.1 micron (or lower) cartridge filter w/ psid gauge.

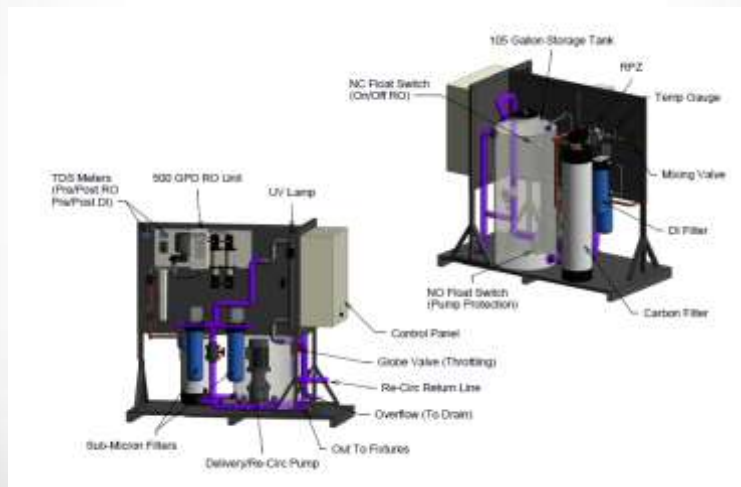


# Commercial RO System Components

- Backpressure Valve:
  - (On recirc return line)
  - Stainless steel
  - Globe or needle valve
  - Used to pressurize loop on continuous recirc systems
  - Pressure gauge required



# Commercial RO System Components



# Commercial RO System Components

- Often pre-plumbed skid systems
- Piping materials
  - Sch. 80 PVC
  - LXT
  - 316 Stainless steel
  - Polypropylene
  - PVDF



# Commercial RO System Sizing

- Critical Information:
  - Application
  - Gallons per day (GPD) water required
  - Gallons per minute (GPM) water required (peak use)
  - Duration of peak use periods/ frequency of use
  - Feed water quality
  - Feed water temperature
  - Product water quality requirements
  - Available space
  - Pumping details (gpm, head)
  - Electrical requirements





# Commercial RO System Sizing

- Example: hospital sterilization system:
  - 3 sterilizers to use 30 gal. per cycle, cycling avg. 2 times per hour X 24 hours. Flow of 10 GPM per unit.
  - Type III water required (5 ppm TDS, 100,000 ohms res.)
  - Delivery pump outlet pressure requirement 55 psi
  - Incoming water quality: 103 ppm of TDS, 6 GPG hardness, 1 ppm cl city water (no Fe, minimal silica)
  - Incoming water temp: 55°F
  - 10' X 20' room available



# Commercial RO System Sizing

- 3 sterilizers to use 30 gal. per cycle, cycling avg. 2 times per hour X 24 hours
  - = 4320 gallons per day (GPD) required
  - = 180 gallons per hour (avg)
- 3 sterilizers at 10 GPM = max GPM flow: 30 GPM



# Commercial RO System Sizing

- Selected RO Unit:



- Produces 7000 GPD @ 77°F
  - = 292 GPH production
  - = min 96% rejection rate = max 4 ppm TDS in permeate
- 5000 GPD system was NOT selected!
  - Extra capacity “buffer” needed
  - Running system close to capacity = BAD

# Commercial RO System Sizing



- Selected Storage Tank:
  - 500 gallon, vertical, polyethylene tank
  - At normal use (2 cycles per sterilizer per hour), tank full
  - Enough capacity to withstand 2 hours of double use! (4 cycles per hour, per sterilizer)
  - Includes high level float switch for RO unit operation
  - Includes low level float switch for pump shutdown, 1” recirc return line, including stainless globe valve and pressure gauge

# Commercial RO System Sizing



- Other Selected Components:
  - Twin, alternating water softener:
    - 90,000 grains capacity/tank (system regeneration 4-5 days)
    - Flow of 10 GPM (system feed rate) at 3 psid
  - Twin, alternating carbon filter:
    - 8 cu. ft. GAC/ tank = approx: 2.8 mil. gal of 1 ppm cl removal
      - X 2 tanks = 5,600,000 gal of cl removal
        - = approx 3 years service before media replacement

# Commercial RO System Sizing

- Other Selected Components:
  - Repressurization Pumps:
    - 2 pumps
      - Stainless, 5 HP, centrifugal
      - Each pump: 30 GPM @ 60 psi
      - Pumps wired for alternating service (redundancy)
  - UV Germicidal Lamp:
    - 39.1 GPM rating @ 30 mJ/cm<sup>2</sup> (99.9% kill rate)
    - Includes UV and lamp life monitor w/BMS output
    - Followed by 0.1 micron cartridge filter array





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# Questions?



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