
WCC
CELEBRATING
50
ANNIVERSARY
1971 - 2021

Where NATURE & SCIENCE meet™

Commercial High-Purity Water Systems & Applications

Brian Soderholm
Brian.Soderholm@watercontrolinc.com
(763) 227-6499

OVERVIEW

- Measuring purity
- Applications and standards
- Production methods
  - Reverse Osmosis
  - Deionization
  - Electrodeionization
  - Distillation
- Pure water delivery systems
- Accessories for ultrapure
- Packaged systems
- System sizing/selection

MEASURING PURITY LEVELS

- "Impurities" = suspended solids, dissolved solids, microorganisms, organics, gases
  - Levels of dissolved solids measured in units:
    - Megohm–cm of resistivity
    - Micromhos/cm [microsiemens/cm] of conductivity
    - PPM (mg/l) of Total Dissolved Solids)
      - (approx. micromhos X 0.67)

Conductivity	Resistivity
0.01 uS	100 MΩ
0.055 uS	18.0 MΩ
0.1 uS	10 MΩ
1 uS	1 MΩ
10 uS	0.1 MΩ
100 uS	0.01 MΩ
1 mS	1 kΩ

APPLICATIONS & STANDARDS

GENERAL LABORATORY AND CHEMISTRY APPLICATIONS

ASTM D-1193

ASTM Reagent Water Types *

Parameter	Type I	Type II	Type III	Type IV
Resistivity @25° C (megohm-cm)	18	1	4	0.2
Conductivity @25° C (µS/cm)	0.056	1	0.25	5
pH @25°C	N/A	N/A	N/A	5.0 - 8.0
Total Organic Carbon (TOC) (µg/l)	50	50	200	No Limit
Sodium (µg/l)	1	5	10	50
Chloride (µg/l)	1	5	10	50
Silica (µg/l)	3	3	500	No Limit
*Water suitable for use in chemical analyses				

Optional Microbiological Limits**

Parameter	Type A	Type B	Type C	
Max hetotrophic plate count (CFU/ml)	0.01	0.1	10	
Endotoxin (EU/ml)	0.03	0.25	N/A	
**May be specified in conjunction with Type I, II, III, or IV Reagent water, as needed				

APPLICATIONS & STANDARDS

SEMICONDUCTOR MANUFACTURING

ASTM D5127

ASTM Recommended Semiconductor Rinsewater Quality Requirements

	Type E 1	Type E 1.1	Type E 1.2
Parameter			
Linewidth (µm)	1.0-0.5	0.35-0.25	0.18-0.09
Resistivity @ 25°C (megohm-cm)	18.1	18.2	18.2
Total Organic Carbon (TOC) (µg/l)	5	2	1
Dissolved Oxygen (µg/l)	25	10	3
Residue after evaporation (µg/l)	1	0.5	0.1

APPLICATIONS & STANDARDS

PHARMACEUTICAL

USP-NF 24

USP24 Water Quality Standards (Pharmaceutical Industry)

	USP Purified*	USP Sterile**	USP WFI***
Parameter			
Conductivity (µS/cm)	1.3	N/A	1.3
pH	5.0-7.0	5.0-7.0	5.0-7.0
Chloride (mg/l)	0.5	0.5	0.5
Sulfate (mg/l)	1	1	1
Ammonia (mg/l)	0.03	0.03	0.03
Calcium (mg/l)	1	1	1
Carbon dioxide (mg/l)	5	5	5
Total organic carbon (TOC) (µg/l)	500	N/A	500
Bacteria (CFU/ml)	100	pass sterility test	0.1
Endotoxin (EU/ml)	0.25	0.25	0.25

*Purified water for compounding
**Sterile water for irrigation
***Water for injection

APPLICATIONS & STANDARDS

HEMODIALYSIS

AAMI RD62

AAMI Water for Hemodialysis Standard

Parameter	Limit (mg/l)
Aluminum	0.01
Chloramine	0.1
Chlorine	0.5
Total Chlorine	0.1
Copper	0.1
Fluoride	0.2
Lead	0.005
Nitrate	2
Sulfate	100
Zinc	0.1
Antimony	0.006
Arsenic	0.005
Barium	0.1
Beryllium	0.0004
Cadmium	0.001
Chromium	0.014
Mercury	0.0002
Selenium	0.09
Silver	0.005
Thallium	0.002
Bacteria	<100 CFU/ml (ANSI)
Endotoxin	<0.25 EU/ml

APPLICATIONS & STANDARDS

MEDICAL FACILITIES

CLSI Reagent Water Specification GP40

Clinical & Laboratory Standards Institute (CLSI): Reagent Water Specification

Parameter	Limit
Resistivity @25°C (megohm-cm)	> 10
Total organic carbon (TOC) (µg/l)	< 500
Particles (max micron filtration)	≤ 0.2
Bacteria (CFU/ml)	< 10

CLSI Water For Autoclaves*

Parameter	
Resistivity @ 25°C (megohm-cm)	0.1
Silica (mg/l)	1

*formerly known as NCCLS/CLSI Type III Water

APPLICATIONS & STANDARDS

HVAC FEEDWATER

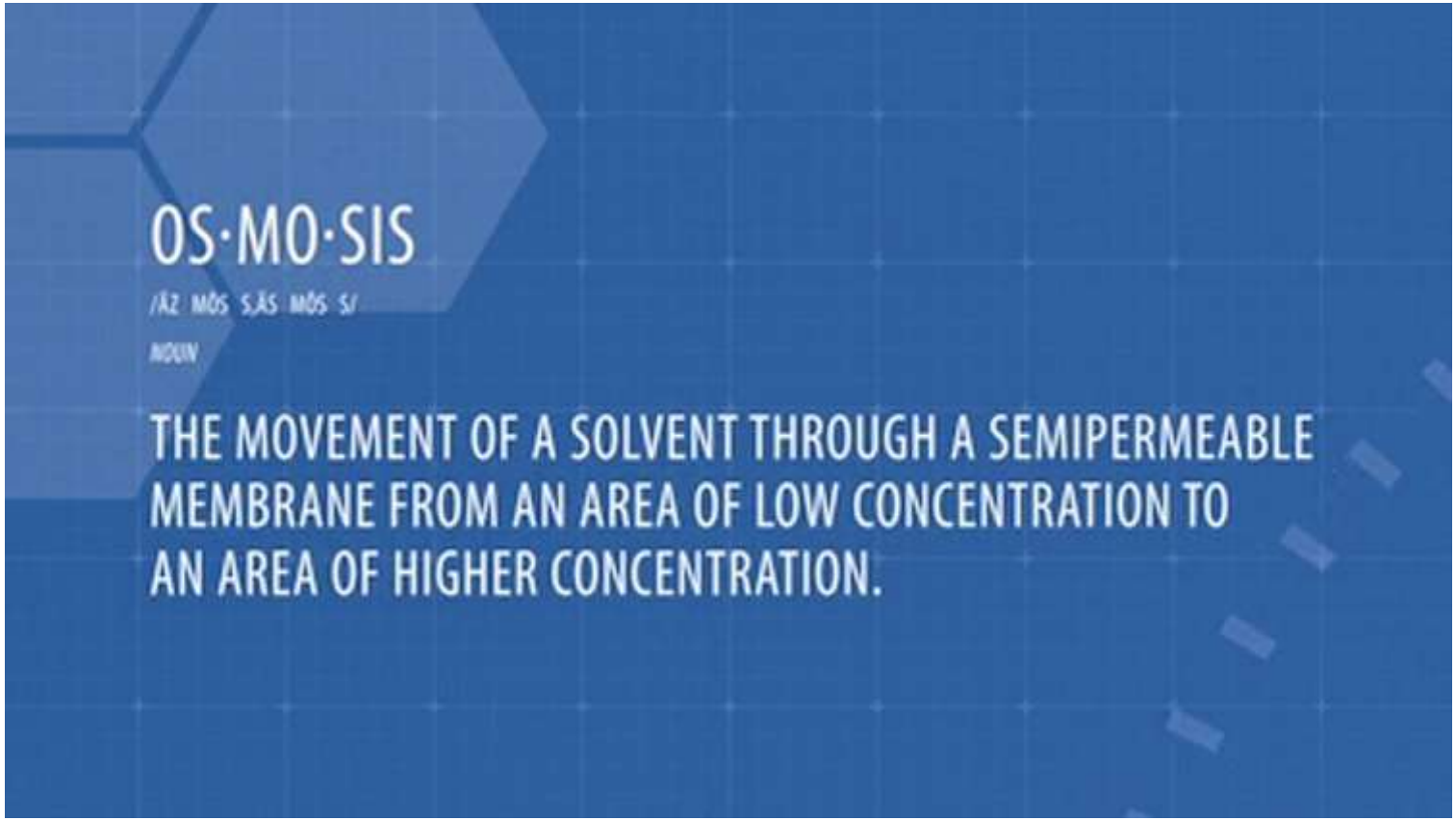
- Humidification, boilers, steam, etc.
- Meet manufacturer specifications
- Typically <15 µS/cm conductivity (approx. 10ppm)
- “Clean Steam” is application and equipment-dependent
  - Condensate typically USP WFI-grade if for pharma

APPLICATIONS & STANDARDS

DRINKING WATER

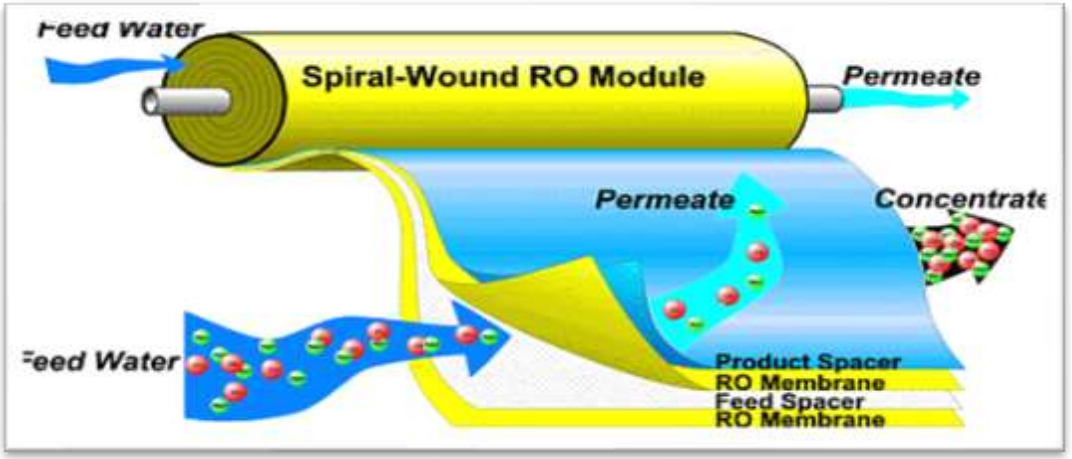
- Must not exceed USEPA Maximum Contaminant Level (MCL) guidelines

PRODUCTION METHODS: REVERSE OSMOSIS

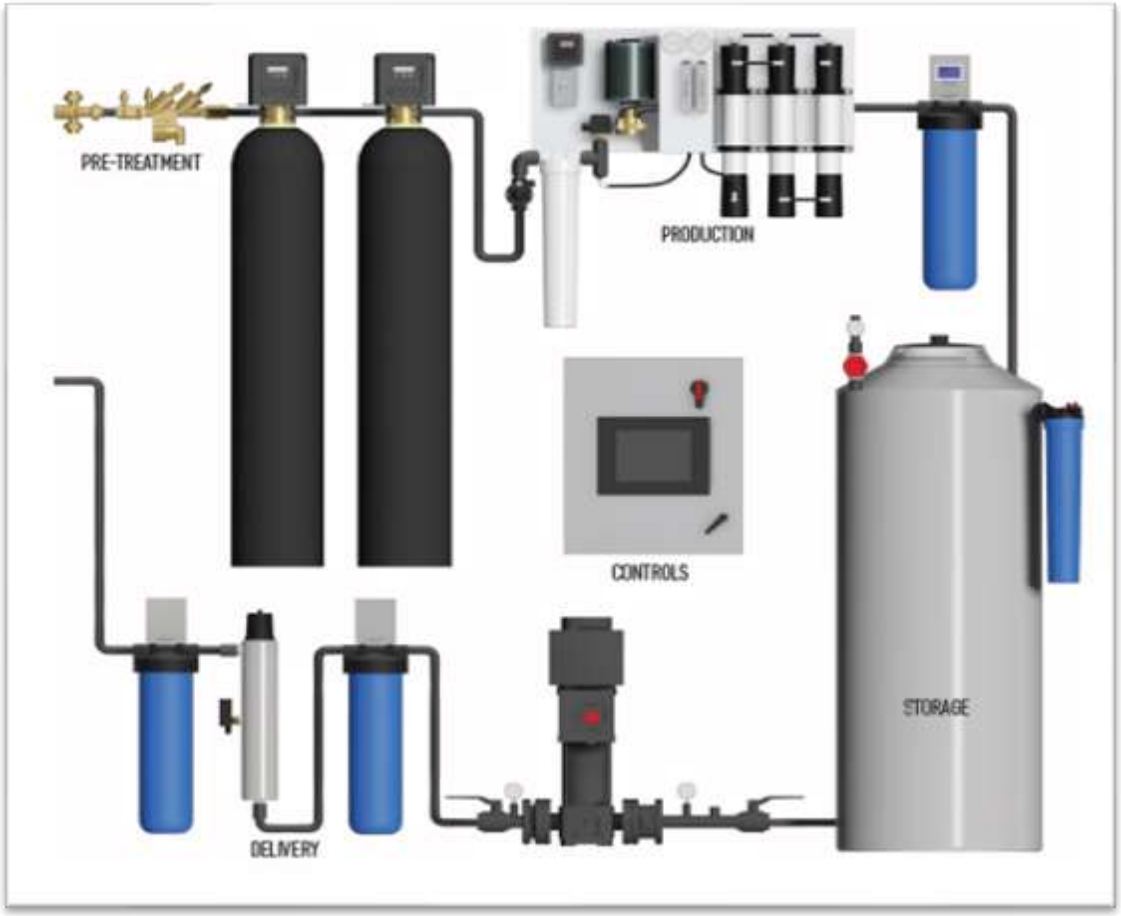


PRODUCTION METHODS: REVERSE OSMOSIS

- 96%-99% NaCl Rejection
- 120 – 180 psi
- 50%-75% recovery
- Rated at 77°F feed temperature
- Chlorine/oxidant-sensitive
- Many variations



PRODUCTION METHODS: REVERSE OSMOSIS



PRODUCTION METHODS: REVERSE OSMOSIS

THERMOSTATIC MIXING VALVE

- (Pre-RO unit) (Optional)
- 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
- Low-energy membranes may reduce need

PRODUCTION METHODS: REVERSE OSMOSIS

REDUCED PRESSURE ZONE BACKFLOW ASSEMBLY (RPZ)

- Prevents contamination of domestic water
- Air gap funnel with pipe to drain
- Usually code-mandated at pure water system feed (pre-RO)

PRODUCTION METHODS: REVERSE OSMOSIS

WATER SOFTENER

- (Pre-RO unit)
- Removes calcium, and hardness
  - Replaces with sodium
- Protects membranes from scaling
- Twin/alternating for 24/7 service

ALTERNATE OPTIONS

- Anti-scalant chemicals
  - (critical with high silica!)
- Template-Assisted Crystallization (TAC)

PRODUCTION METHODS: REVERSE OSMOSIS

CARBON FILTER

- (Pre-RO unit)
- Granulated activated carbon
- Removes chlorine/ chloramine (membrane protection)
- Media replacement every 3-5 years (typical)
- Twin alternating for 24/7 service

PRODUCTION METHODS: REVERSE OSMOSIS

SEDIMENT FILTERS

- (Pre-RO unit)
- Pre-screen suspended solids/debris
- Cartridge, bag, basket, carbon block, UF, etc.
- Monitor PSID

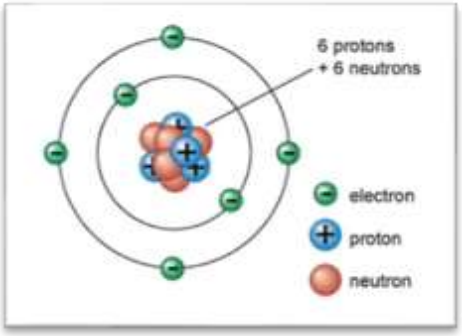
PRODUCTION METHODS: REVERSE OSMOSIS

REVERSE OSMOSIS UNIT

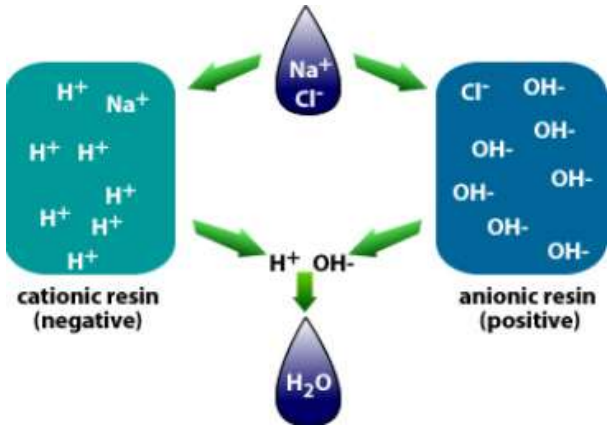
- Solenoid valve, pre-filters, pump(s), membranes, flow meters, pressure gauges, controls
- 100 – 500,000+ GPD
- Concentrate recycle (optional)
- Adjustable bypass (optional)
- Dual-pass setup for 99.9% rejection (optional)

PRODUCTION METHODS: DEIONIZATION

- Atoms and molecules often either “donate” -- or “steal” electrons, making them electrically polarized. These polarized particles are called “Ions.”
  - Cations = “donate” electrons (= +++ polarization)
    - Ex: calcium, iron, magnesium, sodium, copper, aluminum, etc. (metals + hydrogen)
  - Anions = “steal” electrons (= --- polarization)
    - Ex: silica, bicarbonates, sulfate, chloride, fluoride, etc.
  - Cations + Anions = balanced molecules (salts)
    - Ex: calcium bicarbonate
    - Ex: sodium chloride
  - Removing dissolved solids = removing ions (in large part)



PRODUCTION METHODS: DEIONIZATION



- Ion exchange:
  - Cations to hydrogen (H), anions to hydroxide (OH)
- Media needs frequent regeneration when DI used as primary treatment method
  - Hydrochloric acid for cation resin
  - Sodium hydroxide for anion resin
  - Usually done off-site
    - Frequent, expensive exchange services!

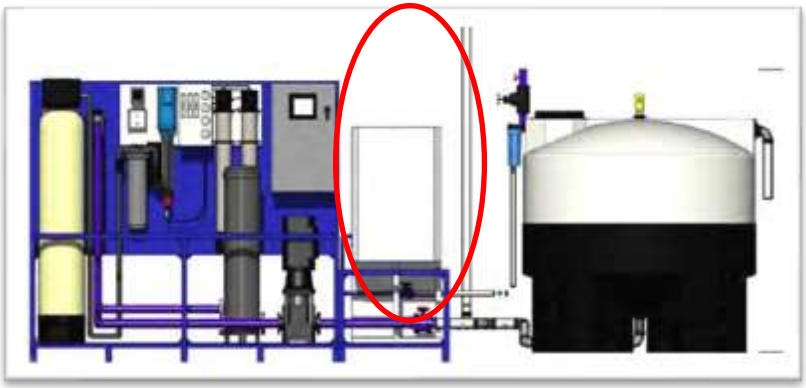
PRODUCTION METHODS: DEIONIZATION

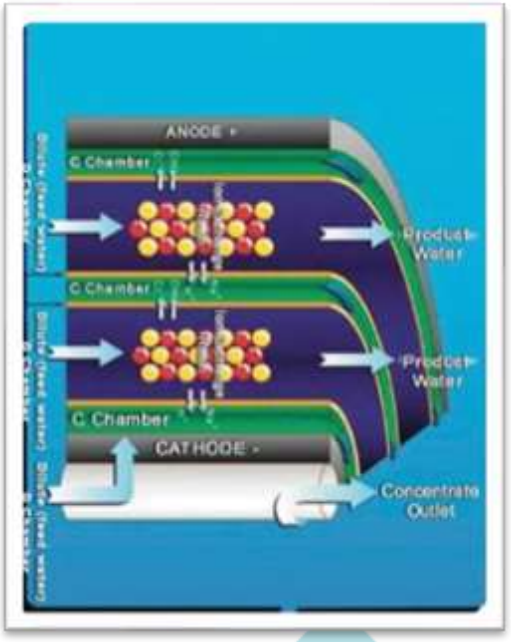
- Nowadays more common to use DI downstream of Reverse Osmosis, to further "polish" the water.
  - Typically use "mixed bed" DI media (anion + cation)
  - Cartridges, tanks, or hybrid
  - Different grades -- can take standard RO water up to 18 megohm-cm (ultrapure)
  - Also used on distribution loops to maintain water quality (ultrapure)

PRODUCTION METHODS: EDI

EDI (ELECTRODEIONIZATION)

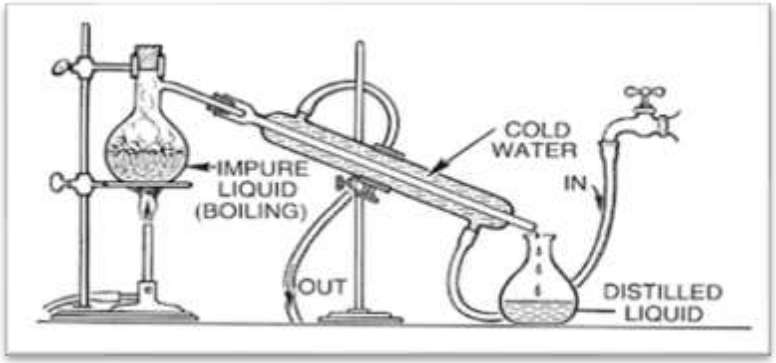
- Polishing after Reverse Osmosis (ultrapure)
- Ions removed by membranes loaded with DI media and driven by an electric charge (electrodialysis)
- DI media continuously regenerated as some water separates into H and OH
- 2 streams of water (approx. 10% reject)





PRODUCTION METHODS: DISTILLATION

- Boil water, capture pure steam and condense back into liquid
- Standard purification method for centuries (mostly replaced by RO/DI)
- Now primarily for USP applications (high temps desirable)
  - Often downstream of RO



DELIVERY SYSTEMS

ATMOSPHERIC STORAGE TANK

- HDPE (typical) or PP/SS (high-temp)
- 100 – 5000 gallons (typical)
- Cone bottom
- Tank level sensor
- Overflow, drain valve, suction outlet
- Recirc return with throttling valve (optional)
- Tank vent filter (HEPA)
- Nitrogen feed and relief valves (optional)

DELIVERY SYSTEMS

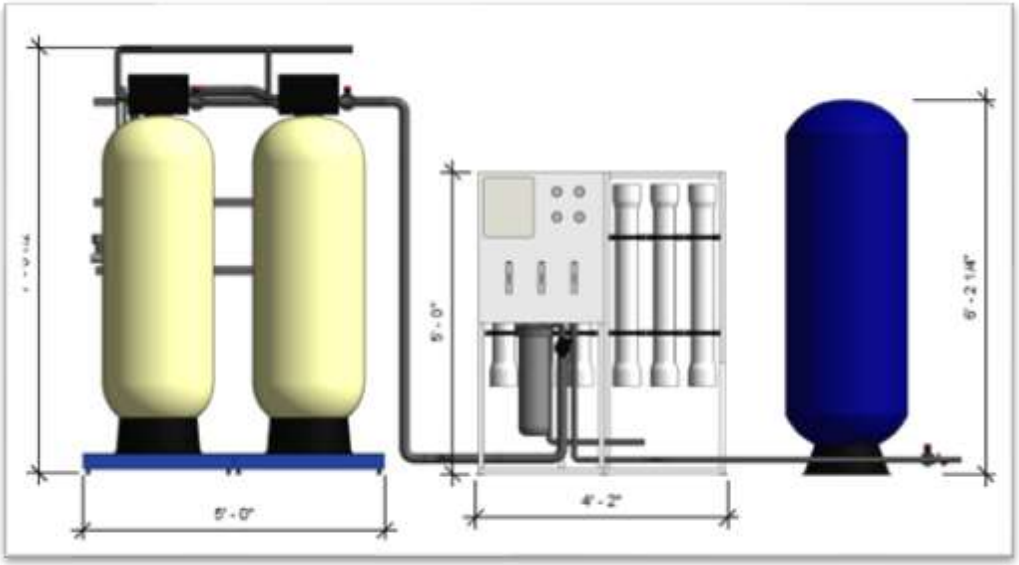
DELIVERY PUMP(S)

- Re-pressurize water for fixtures/equipment
- Stainless steel (316 or better)
- Polypropylene (mag-drive)
- Redundant pump recommended
- Continuous operation, pressure switch, and/or VFD control

DELIVERY SYSTEMS

DIRECT FEED WITH HYDROPNEUMATIC STORAGE TANK

- Constant-volume systems (usually HVAC)
- Fiberglass tank with special bladder
- 30 – 120 gallons (typical)
- Pressure sensor control



DELIVERY SYSTEMS

ULTRAVIOLET LAMP(S)

- Inactivate microorganisms
- TOC reduction
- UV light/lamp monitor
- Followed by sub-micron cartridge filter or Ultrafiltration unit (<0.2µ)

DELIVERY SYSTEMS: PURE WATER PIPING

PURE WATER PIPING MATERIALS

- Sch. 80 PVC (solvent)
- LXT (solvent)
- 316 stainless steel
- Polypropylene (heat)
- PVDF (heat)
- Sanitary valves with minimal risk for bacteria growth
- 3-5 ft/sec velocity target

ULTRAPURE ACCESSORIES

TOC REDUCTION

- Total Organic Carbon
- 185nm UV light
- Ultrafiltration pre-feed
- Adv. oxidation (O3 + H202) pre-feed

REDUCTION OF DISSOLVED GASES

- O2, C02
- Nitrogen blanketing of tanks
- Dissolved gas scrubbers
- Pre-injection of caustic

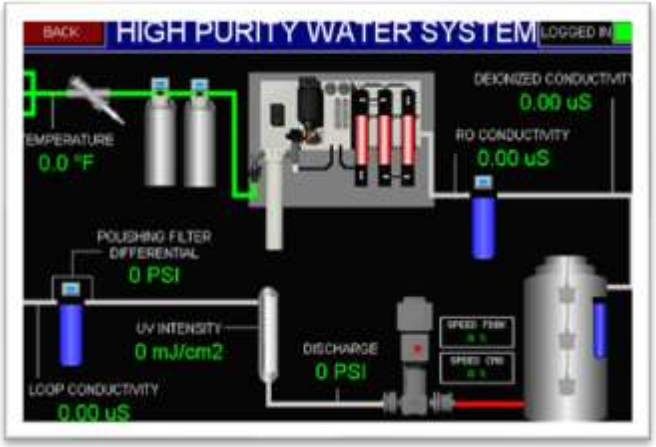
TEMPERATURE CONTROL

- Heat exchangers
- Water heaters
- Chilled water

PRE-PACKAGED SYSTEMS

RECOMMENDED!

- Reduced installation errors
- Warranty
- Integrated components and controls
- Ease-of-connectivity
- Water quality monitoring
- Sample and disinfection ports (ozone/chemical treatment)



HIGH-PURITY SYSTEM SIZING

CRITICAL INFORMATION

- Application
- Gallons per day (GPD) water required
- Duration/frequency of peak use
- Delivery requirements (GPM, pressure)
- Feed water quality
- Feed water temperature
- Product water quality requirements
  - (What standard needs to be met?)
- Available space
- Electrical supply

Brian Soderholm
Brian.Soderholm@watercontrolinc.com
(763) 227-6499

Legionella &
Pathogen Control

Water Reclamation

High-Purity Systems (RO/DI)

Water Softening & Filtration

Advanced PLC Controls


WCC
CELEBRATING
50
ANNIVERSARY
1971 - 2021