Needs Analysis for High Purity Water System Design

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…OF all the Earth's Water

- Oceans cover 71% of the earth's surface and contain 97% of all the water
- The remaining 3% is fresh water!
  - 75% of that is locked up in polar icecaps
  - 24% of that is stored too deep beneath the surface to get to
  - That leaves 1% of the 3% left in lakes, rivers, and accessible aquifers (20% of that is in the Great Lakes)

Municipal & Community Drinking Water

Improved drinking water

High Purity Water

- One of best solvents in the world
- Applications
  - Cleaning/Rinsing
  - Steam Generation
  - Dilution
  - General use
- Markets
  - Pharma
  - Power
  - Semiconductor
- Each industry has its own specifications and consequences for being out of compliance
  - Driven by instrumentation and monitoring

Food & Beverage

CRITICAL ISSUES AND APPLICATIONS

High purity water for ingredient, beverage and fluid mixing
Process water
Utility water for production
Boiler feed water make-up
Clean in place
Wastewater minimization
Sanitization

Food Service / Restaurants

WATER TREATMENT USES
Boiler/hot water heater pre-treatment
Dish washers and glass washers
Steamers and steam tables
Drinking water and coffee filtration
Beverage and ice pre-filtration

Oil & Gas

CRITICAL ISSUES AND APPLICATIONS
RO or ultra-softwater water for oil field steam injectors
Cooling tower make-up water
Oil platform drinking water systems
Wastewater discharge for regulatory compliance
Micro-organism control
Water re-use and wastewater minimization

Energy & Power

CRITICAL ISSUES AND APPLICATIONS
Boiler and cooling tower makeup water
Cooling tower re-use
Waste water discharge quality compliance
Overall onsite water management and wastewater minimization
Condensate polishing
High pressure boiler feed water specifications

Educational Facilities

WATER TREATMENT USES
Boiler / hot water heater pre-treatment
Cooling towers & chillers
Food service / beverage & ice filtration
Athletic programs
Custom teaching facilities (i.e. science labs)

Grocery

WATER TREATMENT USES

Produce misters - water treatment
Vended water
Food & beverage preparation
Cooling & chilling systems
Drinking water systems

Small Manufacturer
High-quality water, promotes consistent production.

WATER TREATMENT USES
Boiler / hot water heater pre-treatment
Process applications
Cooling & chilling systems
Drinking water appliances

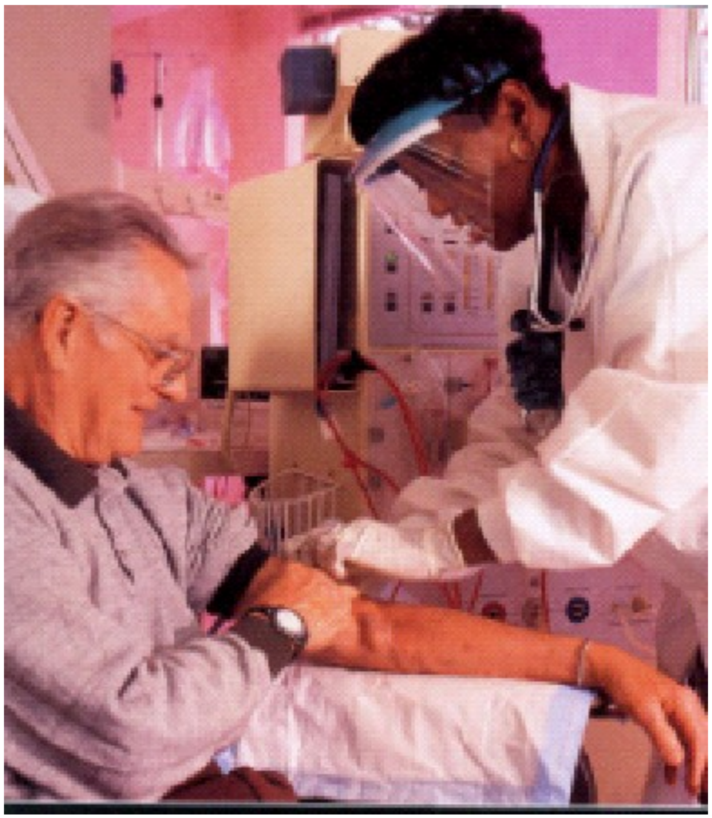
Healthcare / Hospitals / Biopharmaceutical

CRITICAL ISSUES AND APPLICATIONS
Multi megaohm *ultra-pure* water
UV sanitization and sterilization
Factory Acceptance Testing (FAT, IQ, OQ, PQ)
Validated Acceptance Testing (VAT)

Healthcare Professionals

WATER TREATMENT USES
Boiler / hot water heater pre-treatment
Cooling towers & chillers
Food service
Laundry facilities
Laboratories & research rooms

Hemodialysis



Cleans the blood by ridding the body of harmful wastes, extra salts and fluids.

Controls blood pressure and helps the body keep a proper balance of electrolytes such as potassium, sodium, and chloride.

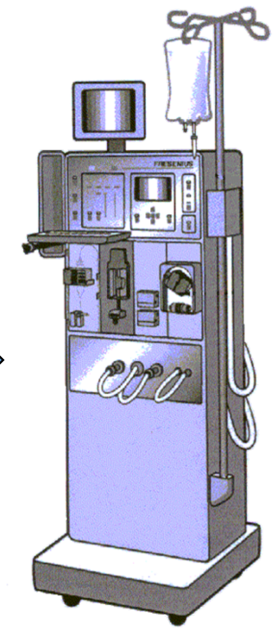
Dialysis Equipment Process Overview

Source Water

Municipal Tap or Well

Water Tx System

Filtration
De-chlorination
Softening
Reverse Osmosis
Deionization
Ultra-Filtration



Dialysis Equipment

Filters blood, removes Toxins & excess fluids; Mixes & Monitors the Dialysis Solution From Purified Water & Concentrates

Dialysis Patient

Why “Treat” the Water for Hemodialysis ?

Why Water Must be Treated

Average Person

- Drinks 14 liters of water/week
- GI tract more selective
- Functioning kidney

10 – 14

Liters

Person on Hemodialysis

- Blood is exposed to 360+ liters of water/ week
- Dialyzer membrane is thin, non-selective
- Nonfunctioning kidney
- <u>Can experience harm or death from untreated water</u>

350 – 450

Liters

Fresenius Medical Care

HOW IS A DESIGN SELECTED?

- CUSTOMER PREFERENCE
- CLEANLINESS OF FEEDWATER
- WATER QUALITY REQUIRED
- WATER QUANTITY REQUIRED
- WASTEWATER VOLUME

Comparison of Drinking Water and Dialysis Water Standards*		
Contaminant	SDWA National Primary & (Secondary) Drinking Water Regulations, mg/L**	Dialysis Water: AAMI/ANSI Maximum Allowable Chemical Contaminant Levels, mg/L***
Aluminum	0.05 – 0.2	0.01
Arsenic	0.05	0.005
Barium	1.0	0.1
Cadmium	0.005	0.001
Calcium	—	2.0
Chloramine as Cl_2	4.0 MRDLG	0.1
Chlorine (free) as Cl_2	4.0 MRDLG	0.5
Chromium	0.05	0.014
Copper	1.0 & 1.3 TT Action Level	0.1
Fluoride	2.0 & 4.0	0.2
Lead	0.015 TT Action Level	0.005
Magnesium	—	4.0
Mercury	0.002	0.0002
Nitrate (N)	10.0	2.0
Potassium	—	8.0
Selenium	0.05	0.09
Silver	0.1	0.005
Sodium	—	70.0
Sulfate	250	100.0
Zinc	5.0	0.1

Typical Guidelines

Water Standards / Guidelines

	Microelectronics	Power	ASTM		Pharmaceutical
	electronics grade QR 1.2		Type I	Type II	USP27
Conductivity (μS/cm)	.0546	<0.10	<0.056	<1.0	<1.3
Resistivity (MΩ-cm)	18.2	>10.0	18.0	>1.0	>0.769
TOC (ppb)	<50		50	50	<500
Silica (ppb)	<5	<10	<3	<3	none
Bacteria (cfu/ml)	<10	none			<100
Chloride (ppb)	<0.1	<10	1	5	none
Sulfate (ppb)	0.1	<10			none
Sodium (ppb)	<0.5	<10	1	5	none

Variables that may effect system quality

- Changes in pressure or availability to a constant/ consistent municipal water supply.
- Significant changes in pH
- Chlorination – disinfectant type used & residual levels
- Marked increased in levels of Fluoride, Aluminum, Zinc, Sulfates or Nitrates*

Particle Size Scale

0.0001 Micron	0.001 Micron	0.01 Micron	0.1 Micron	1.0 Micron	10 Micron	100 Micron
Dissolved		Suspended				
					Media Filters	
				Cartridge Filtration		
			Microfiltration			
		Ultrafiltration				
	Nanofiltration (crossflow)					
Reverse Osmosis (crossflow)						

One micron = One millionth of a meter

Water Purity Grades (ionic)

- Municipal water: 100-500 ppm TDS
- Reverse Osmosis water 5-80 ppm TDS
- Two-Bed DI water 1-5 ppm TDS
- Mixed Bed DI water .04-.5 ppm TDS

- (pure water will conduct almost NO electricity)

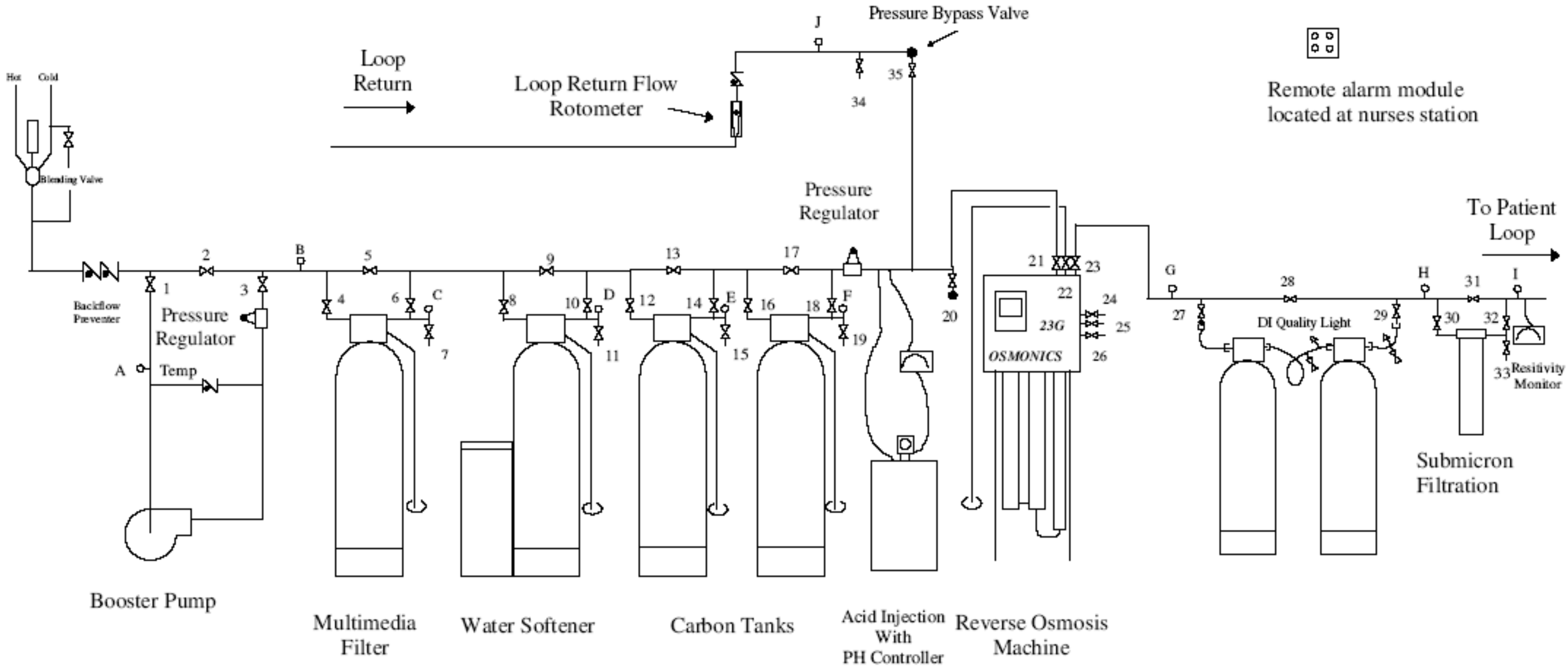
Common System Design

- Pretreatment
  - Multi media / Cartridge filtration
  - Softener
  - Carbon
- Main Treatment
  - Reverse Osmosis
  - Ion exchange
  - Electrodionization
- Post treatment
  - Ultraviolet light
  - Final filtration (absolute barrier)
- Distribution
  - Storage tank
  - Ultraviolet light
  - Point of use filtration

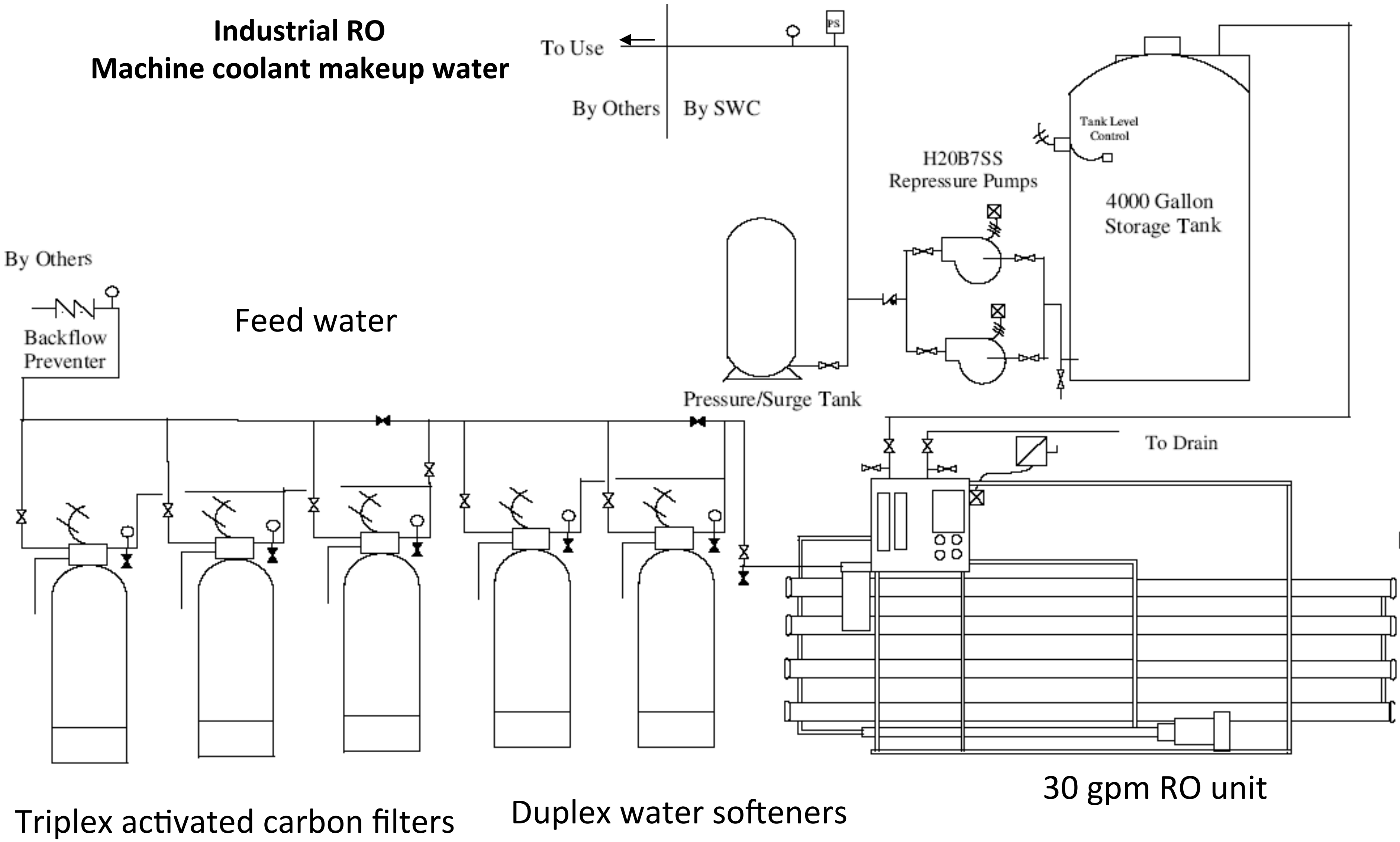
Typical Water Treatment System for Dialysis

Direct Feed RO system

-uses permeate pressure for delivery



Industrial RO
Machine coolant makeup water



Water Softening

- Removes hardness minerals by ion exchange
  - Calcium, Magnesium, Iron are exchanged with Sodium
  - Used for aesthetic improvements for soap savings & scale reduction (laundry, dishware, boiler feed) or pretreat to Reverse Osmosis
  - Uses salt as a regenerant to “refresh” the media; its capacity between regens CAN be calculated accurately

Water Softening (cont.)

- When "salted" at 10 lbs per cubic foot of resin, the softener will be able to "exchange" 25,000 grains of hardness
- If your water supply has 12 grains of hardness in each gallon, each cu.ft. of resin will be able to remove the hardness from 2080 gallons of water.
- If you have a 10 cu.ft. water softener, the capacity between regenerations is roughly 20,000 gallons

Softener Technology Improvements

- Brine Recovery
  - Reclaim a portion of the "Sweet Brine" discharge during regeneration to provide makeup water for next brining cycle
  - Salt savings range from 15-20%
  - Lower environmental impact


HARDNESS
TEST KIT
MODEL 5B

Activated Carbon Adsorption

Adsorbs organics, chlorine, taste, odors

Typically configured in media tank with auto-backwash control valve, and is sized based upon anticipated flow rate and EBCT

Can flow at 7-8 gpm per square foot of media, or 2-2.5 gpm per cu.ft. of media

EBCT

Empty Bed Contact Time

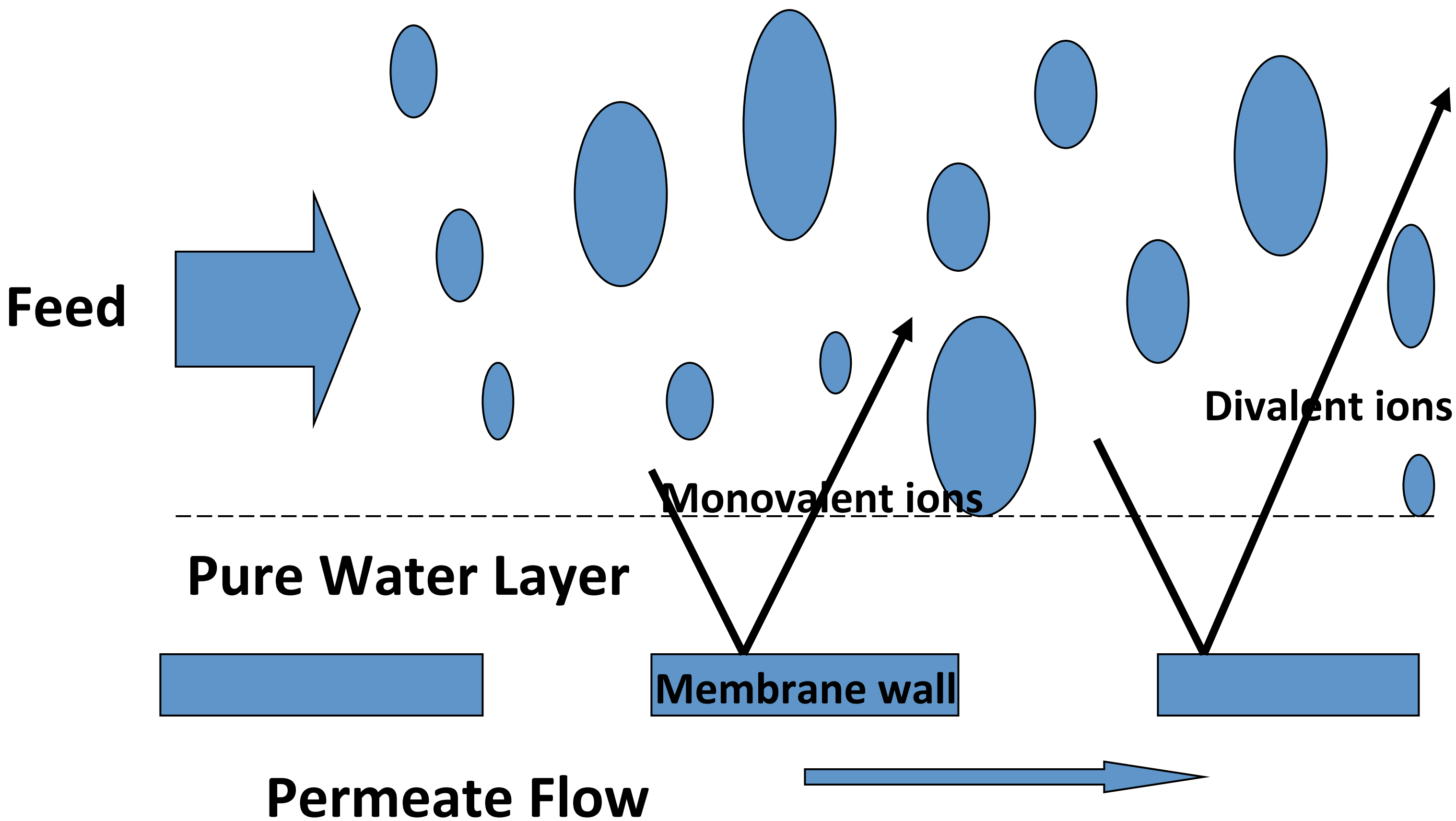
- The amount of time the feed water is in contact with the activated carbon
- For Dialysis, 10 minutes minimum
- For Commercial dechlor: 4-5 minutes
- For Industrial: Application driven

- EBCT = $\dfrac{\text{(cubic feet GAC)x 7.48 gal/cu.ft.}}{\text{GPM feed flow}}$

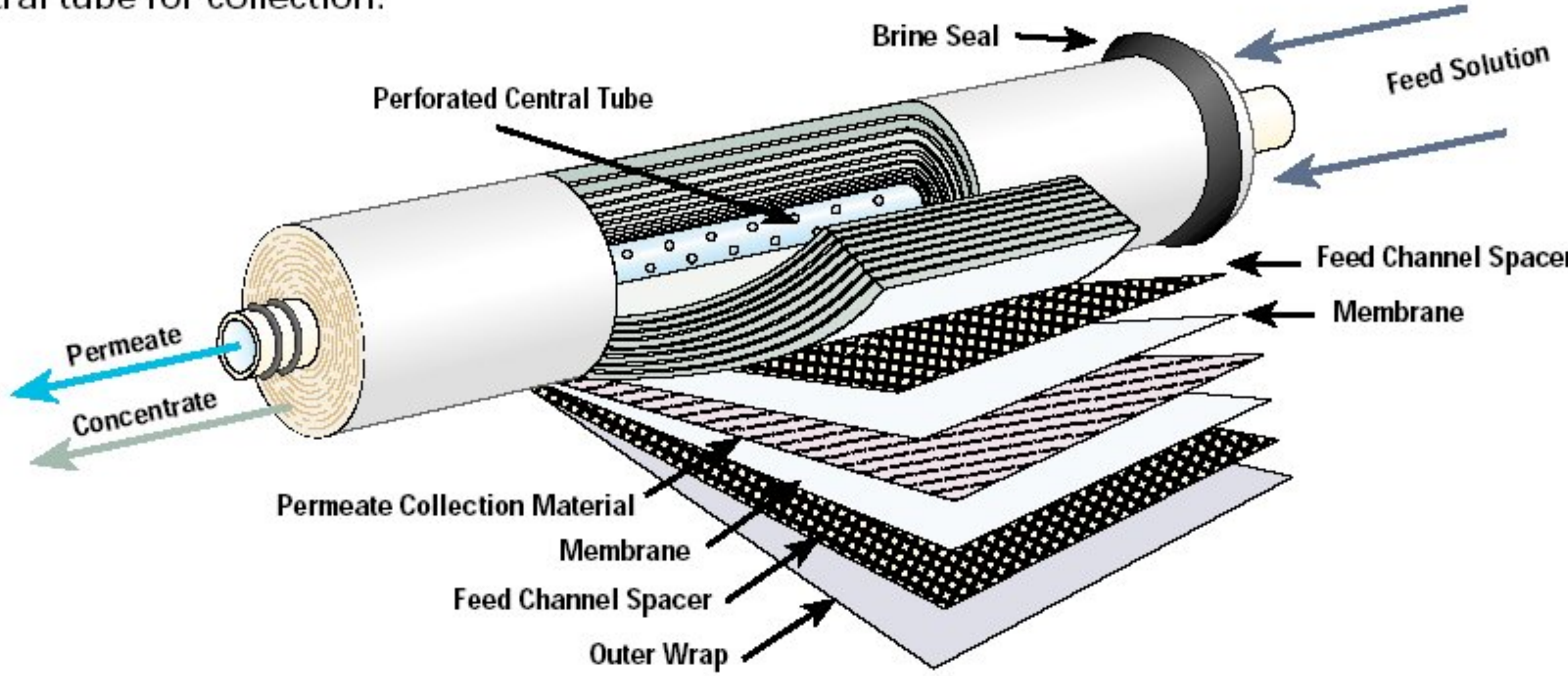
Reverse Osmosis Overview

Reverse Osmosis Theory

Cross Flow Filtration



The spiral membrane is constructed of one or more membrane envelopes wound around a perforated central tube. The permeate passes through the membrane into the envelope and spirals inward to the central tube for collection.



The illustration above represents a simplified spiral-wound membrane element. Recovery can be as high as 90% and systems may be capable of chemical cleaning in place (CIP).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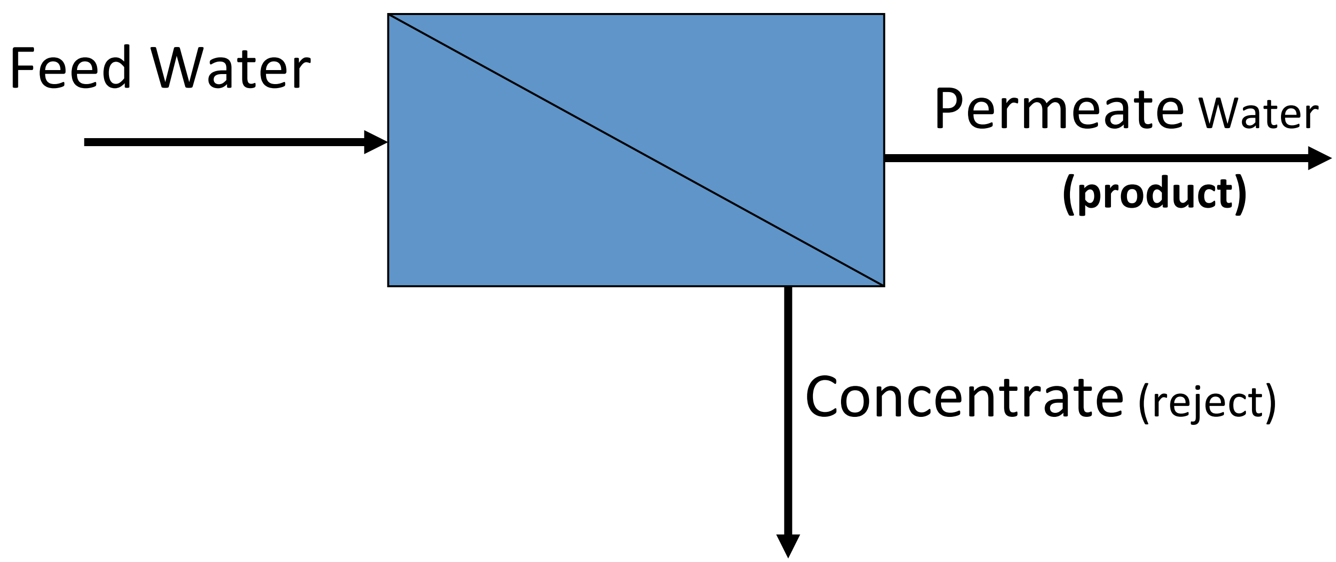
RO Element Recovery

The ratio of permeate flow to feed flow of an individual membrane within an RO machine.

(element permeate rate / feed rate) * 100
Usually a maximum of 15% per element



Reverse Osmosis Terminology

- **Permeate**: the portion of feed solution passed thru the semi-permeable membrane
- **Concentrate**: the portion of feed solution retained by the semi-permeable membrane
- **Passage**: the percentage of dissolved ions which passes thru the membrane with permeate
- **Rejection**: the percentage of dissolved ions which do not pass thru the membrane
- **Low-Energy Membrane Technology**: lower hp required

Example

- Water has TDS (total dissolved solids)

of 500 ppm

- If RO produces 95% rejection the product water will have 25 ppm TDS

Reverse Osmosis Terminology (cont)

- **Recovery**: the ratio of permeate rate to feed rate
- **Concentration Factor**: a measure of how concentrated the concentrate (reject) stream will be for a set recovery

Recovery	Concentration Factor
20%	1.25 x feed
33%	1.5 x feed
50%	2 x feed
66%	3 x feed
75%	4 x feed
90%	10 x feed

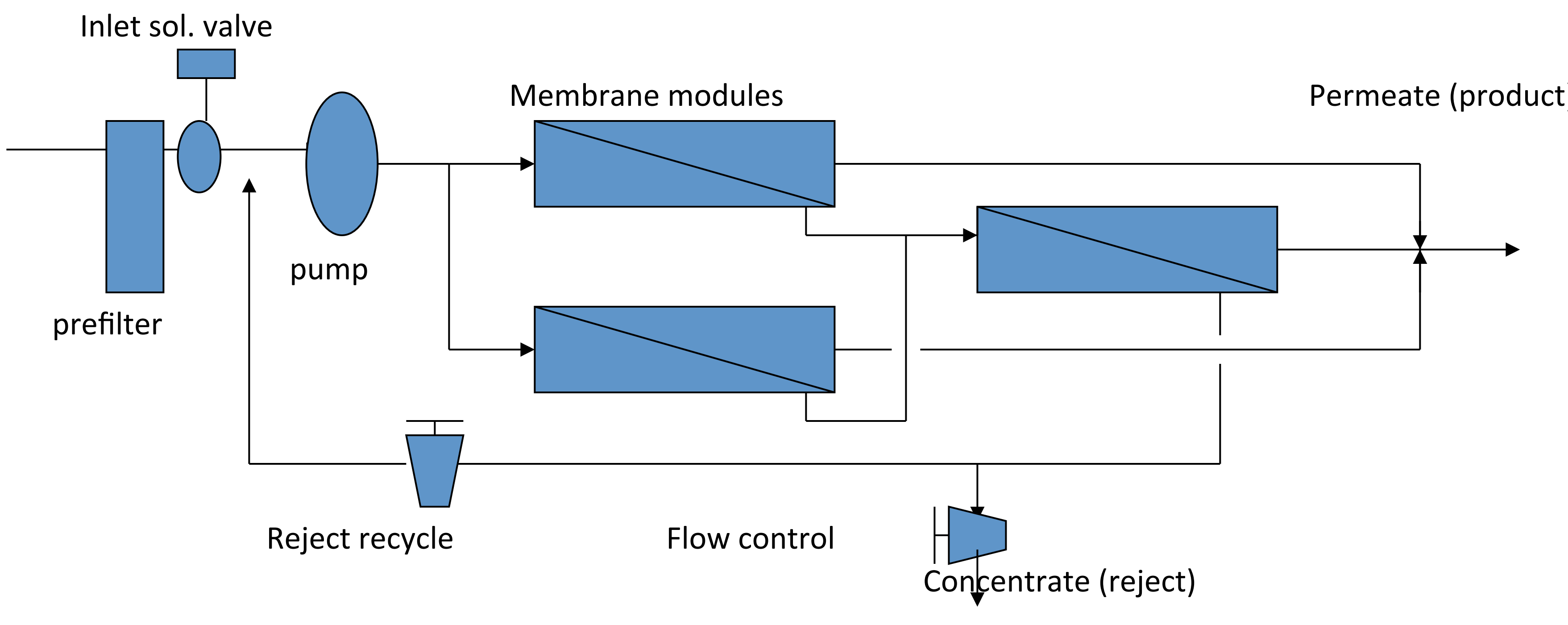
Typical recoveries range from 50-75%

Multi-Stage RO System

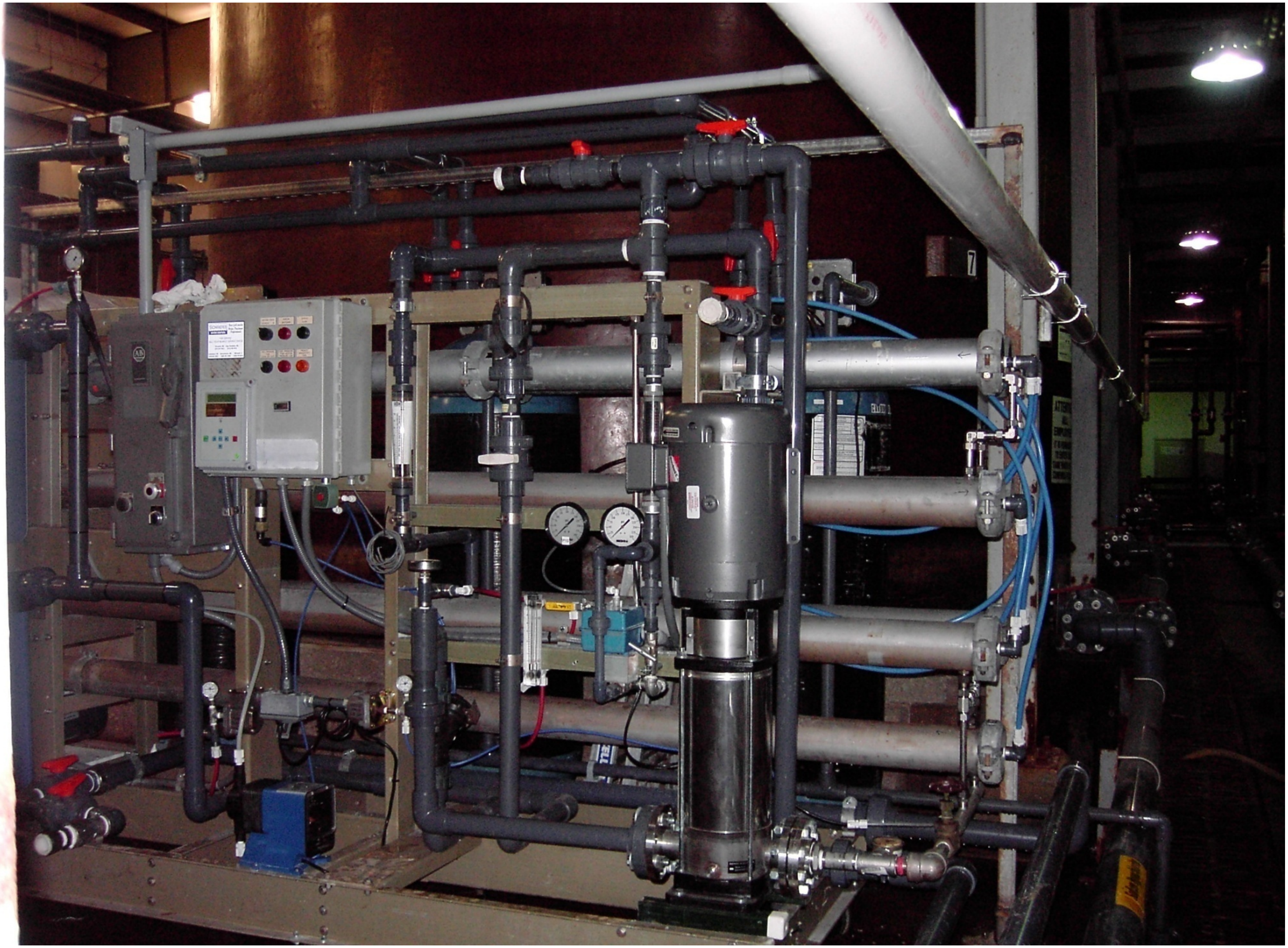
Reject staged

With Reject Recycle

Allows for higher recoveries, reduced pump horse power, and lower feed flow requirements




Reverse Osmosis
Biolab
Equipment
DANGER



Effects of Temperature on Production

- Rated Membrane production is based upon feed water temperature of 77 deg.F

- There is a 1-1.25% effect on product output per 1 degree: Gain if above 77, loss if below 77deg

Consider the effect of pressure on RO Production

- Membrane output has an almost linear relationship with average membrane pressure
- An RO running at 220psi will produce approx. 35% more water than one operating at 160psi.
- If the permeate back pressure is 60psi, an RO operating at 220psi pump pressure will produce like one operating at 160psi


ATTENTION
ALL
EMPLOYEES
IT IS FORBIDDEN
TO ENTER THIS
TANK WHICH IS A
CONFINED PLACE

The Needs Analysis

- **Qualitative Analysis**
  - Finished Water Quality to Meet Internal QC or Industry Standards
  - Different Areas of the Facility May Need Different Quality
  - Instrumentation Requirement to Meet QC Standards
- **Quantitative Analysis**
  - Total Daily Requirement
  - Peak Demand Periods
  - Instantaneous Demand
  - Minimum Flow Rates to Ensure Quality Standard

Quantitative Analysis

- Usually requires cooperative efforts of the engineer, awareness of industry standards, and input/feedback from the end-user.
- Usually requires Site Visits to Gain the necessary understanding of the end-user's process.
- Always requires confirmation by the end-user, preferably in writing

Quantitative Characteristics

- Data is best gathered and organized in Chart or Spreadsheet, sorted by TIME and USAGE
- Data is gathered to represent a typical Peak 24-hour period
- Individual Loads are identified and data collected for each load

TIME PERIOD		GALLONS
4:00 AM	5:00 AM	Maintenance
5:00 AM	6:00 AM	Maintenance
6:00 AM	7:00 AM	
7:00 AM	8:00 AM	
8:00 AM	9:00 AM	200
9:00 AM	10:00 AM	100
10:00 AM	11:00 AM	200
11:00 AM	12:00 AM	300
12:00 AM	1:00 PM	
1:00 PM	2:00 PM	200
2:00 PM	3:00 PM	200
3:00 PM	4:00 PM	250
4:00 PM	5:00 PM	200
5:00 PM	6:00 PM	
6:00 PM	7:00 PM	
7:00 PM	8:00 PM	
8:00 PM	9:00 PM	200
9:00 PM	10:00 PM	100

Usage Patterns

- Batch-Type Usage vs Steady/Continuous Use
- Periods of Inactivity followed by heavy usage
- Maintenance or CIP Clean-In-Place needs
- Time means Money in Production
- Multiple points of use (POU) demands
  – Overlap Cumulative usage
  – Staggered Usage

Storage and Delivery

- Once Usage Patterns are logged, instantaneous needs (GPM and Gallons/Batch) are balanced with Overall Quantity Required

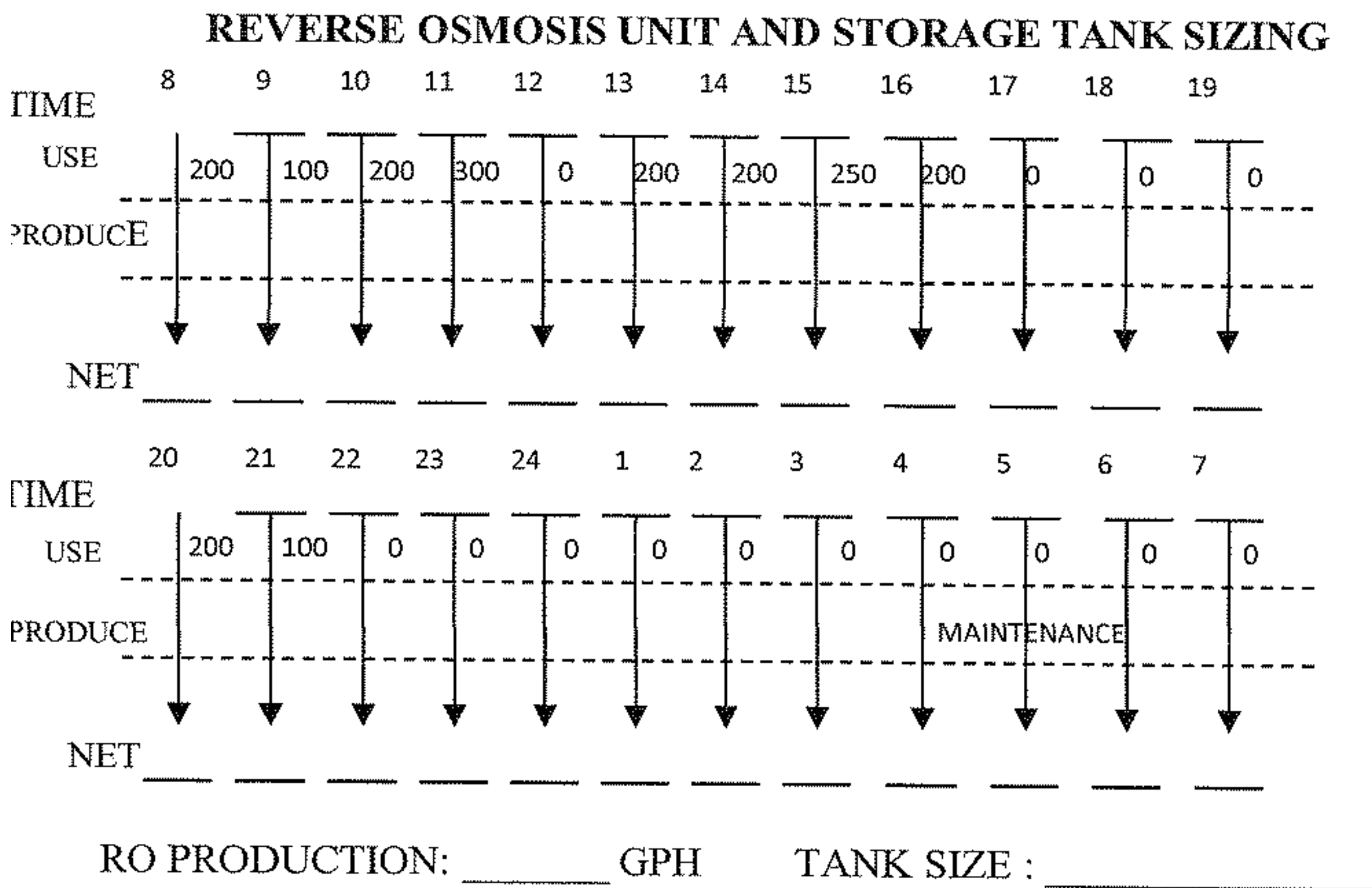
Ex: The daily need for high quality water is 1500 gallons, but 800 of it is needed to fill a batch tank in 20 minutes. Demand is 40 gpm, then 700 gallons over 7 ½ hours (approx 10 gpm).

- Distribution piping will need to be 1 ½”, not 1”.
- Minimum of 800 Gallons of high purity water will need to be produced and stored, ready for that one batch.
- Quality must be kept within tolerance during that storage period, prior to use.

Types of Usage

- Batch process for ingredient production
- Humidification, boiler feed
- Final Rinse down of parts to remove solvents
- Blood analyzers
- Kidney Dialysis
- Laboratory, for glassware rinsing, reagent prod
- Pharmaceuticals
- Machine coolant make up

Needs Analysis Chart

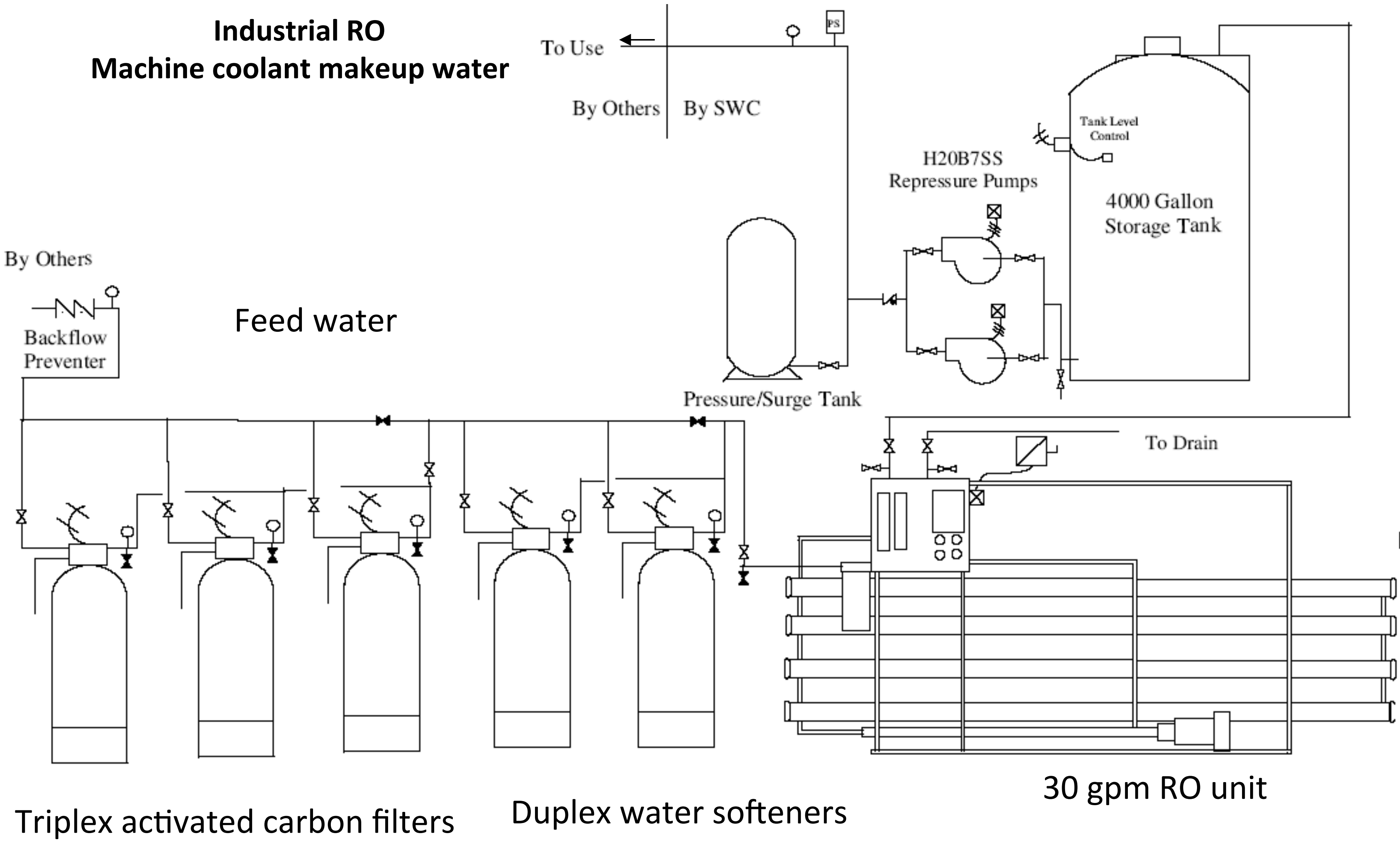


The Needs Analysis Chart

- Illustrates when and where the peak demands in usage occur
- Aids in the sizing of the Storage Tank and the Distribution piping and polishing filters
- Allows the engineer to collaborate with the end-user to consider production patterns that will minimize equipment/distribution sizing(COST) while still maintaining quality.

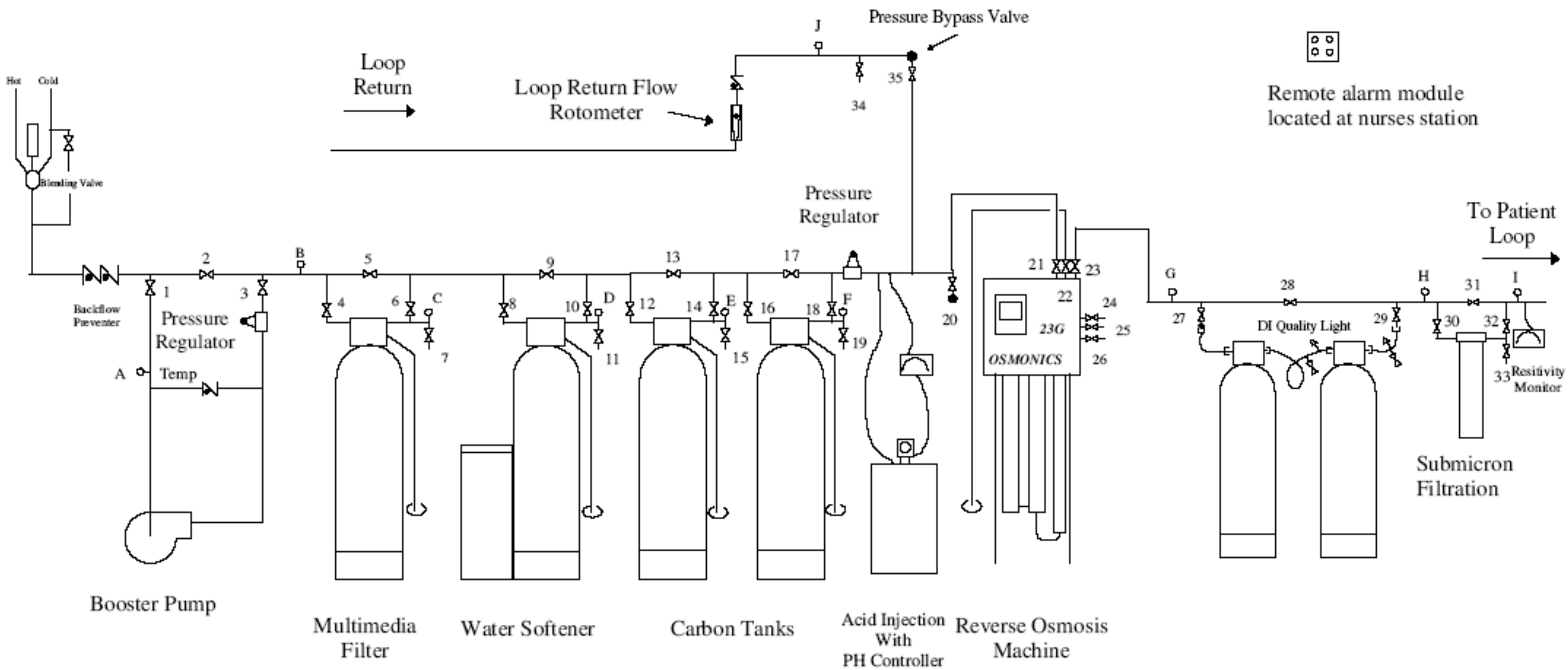
EXAMPLE

Industrial RO
Machine coolant makeup water



Direct Feed RO system

-uses permeate pressure for delivery

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