Water for Hemodialysis

SYSTEM CONSIDERATIONS

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What is our Primary Goal?

To Provide Safe, Adequate Treatments To Our Patients

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SO HOW DO WE PROTECT OUR PATIENTS?

- Education
- Proper water system design
  - Correct type and size of components
  - Chemical compatibility of all materials used in the water treatment system.
- Proper Monitoring
- Compliance to Current Water Treatment Standards

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Why Do I Need to Be Trained On Water Treatment?

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Patient Care Staff are Responsible For Understanding the Clinical Ramifications of Water Treatment

Everyone Must Be Able to Identify Problems with the Water Treatment System Which May Result in a Potential Threat to the Patient's Health and Safety

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HOW CAN I ENSURE MY WATER SYSTEM IS WORKING SAFELY?

- Understand what is in water and how it affects the patient.
- Be knowledgeable about your water treatment system.
- Be alert for problems.
- Monitor your water treatment system correctly and often.

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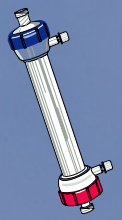
WHY IS WATER AND WATER TREATMENT SO IMPORTANT?



- Water is considered as part of the prescription to the patient.
- Water makes up 90% of the solution used for dialysis (dialysate).
- What happens in the water treatment area can directly affect the patient and has the potential to harm many patients simultaneously.
- Only a semi-permeable membrane separates the patient's blood and dialysate.
  - Even tiny amounts of chemicals and contaminants in the water can be dangerous to the patient.

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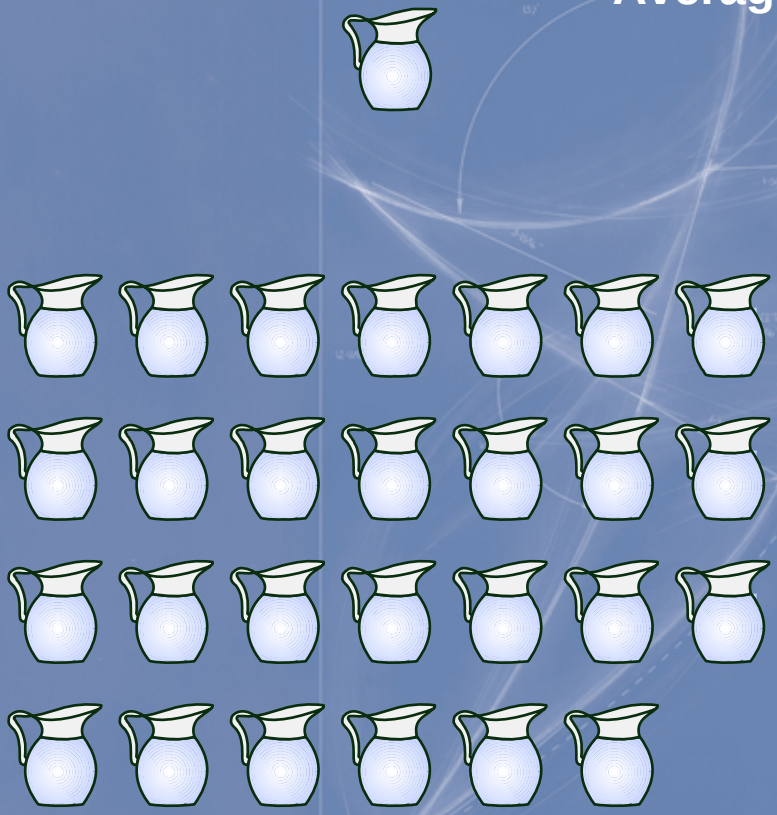
EXPOSURE TO WATER



Average person:

15 Liters / week
Drinking, Recreation
Normal excretion:
gastro-intestinal

Dialysis Patient:

↗ **400 Liters / week**
a lifetime in 3 years
No excretion
Artificial Kidney
process - diffusion
thin membrane
side effects
Even small amounts of contaminants are dangerous to patient

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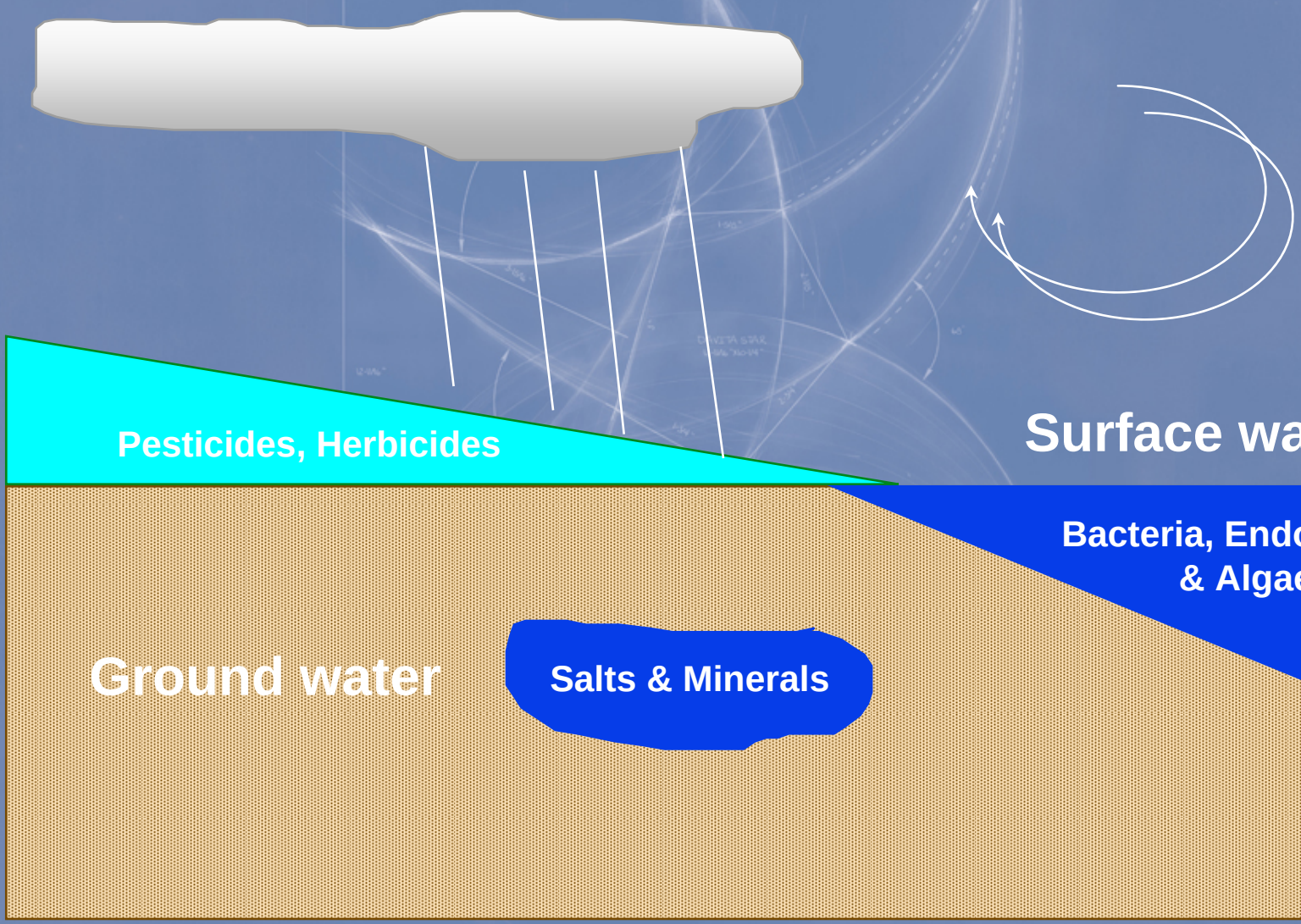
SOURCES OF WATER



TYPES OF WATER

- **Surface Water**
  - Contains varying degrees of silt, mud, dirt, debris, chemicals, metals, toxins
  - Generally contains more organic material than ground water: bacteria, algae, microbials
- **Ground Water**
  - Generally contains more inorganic material; minerals, salts, etc.
  - Some bacteria, algae, organics

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COMPOUNDS IN WATER

- Organics are carbon based; Inorganics are not
  - Organics: Pesticides, Herbicides (and chloramine)
  - Inorganics: Salts, Minerals, Chemicals
- Contaminant levels determined by…
  - Location, season, local industry, contact time
    - Well water - higher salt, calcium; microscopic plants
    - Reservoirs - higher bacteria, viruses; lower salts
  - Municipality adding chemicals for public safety
    - Alum - flocculant; Fluoride - teeth; Chlorine - bacteria

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POSSIBLE CONTAMINENTS IN WATER

Sediment and Particles:	**Sand, Mud, Silt**
Salts and Other Chemicals:	**Calcium, Magnesium**
	Sodium, Potassium
	Fluoride, Chlorine
	Nitrates, Sulfates
Metals and Heavy metals:	**Copper, Zinc**
	Aluminum
	Iron, Tin
Trace Metals:	**Arsenic, Lead, Silver**
	Barium
	Cadmium
	Chromium
	Selenium
	Mercury

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PATIENT CONDITIONS: GENERAL SIGNS, SYMPTOMS, AND CAUSES

Symptom	Possible Cause
Anemia	Aluminum, Copper, Chloramine, Zinc
Bone Disease	Aluminum, Fluoride
Hemolysis	Chloramine, Nitrates, Copper
Hypertension	Calcium, Sodium
Hypotension	Bacteria, Endotoxin, Nitrates
Metabolic acidosis	Low pH, Sulfates
Muscle weakness	Calcium, Magnesium
Nausea/Vomiting	Bacteria, Calcium, Copper, Endotoxin, Low pH, Magnesium, Nitrates, Sulfates, Zinc
Neurological Deterioration	Aluminum

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PATIENT CONDITIONS: EFFECTS OF HIGH EXPOSURE TO TRACE METALS

Arsenic	Vomiting, diarrhea, burning abdominal pain, dehydration, throat constriction, pulmonary edema, liver failure
Barium	Vomiting, diarrhea, abdominal pain, tremors, convulsions, hypertension, cardiac arrest
Cadmium	Vomiting, diarrhea, abdominal cramps, dry throat, cough, dyspnea, headache, shock, coma, renal failure
Chromium	Skin diseases
Lead	Personality changes. metallic taste, anorexia, abdominal pain, vomiting, constipation, neurological problems
Mercury	Acute: Vomiting and diarrhea, salivating, abdominal pain, burning mouth pain, uremia
	Chronic: Gingivitis, mental disturbance, neurological
Selenium	Loss of hair and nails
Silver (N)	Vomiting, diarrhea, shock, vertigo, convulsions

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SYSTEM DESIGN

- The source water is analyzed to determine the highest possible levels of contaminants. Factors considered may include:
  - Source of Water
  - Bacterial load
  - Temperature fluctuations
  - In-organic contaminant level testing
  - Available water pressure
  - Silt content
  - pH
- Only after the water analysis is complete and all factors are considered, is the necessary equipment selected.

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WATER TREATMENT STAGES

Pretreatment

Purification &
Distribution

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PRETREATMENT PROCESS

- Patient Protection
  - Chlorine & chloramine removal
- Component Protection
  - Chlorine removal
  - Hardness removal
  - Particle removal
- Optimum operating pressure & temperature

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PRETREATMENT COMPONENTS

- Blending/Tempering Valve
- Booster Pump
- Particle Filters
- Softener
- Carbon Filters
- On-Line Monitors & Sample Taps

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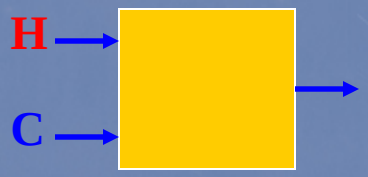
PRETREATMENT DIAGRAM
BLENDING VALVE



BLENDING VALVE

BLENDING VALVE

- Optimal & stable water temperature
  - Stable RO water production
  - Optimal carbon filter operation
- Flow range requirements
  - Dialysis operations
  - Backwash & regeneration cycles
- Monitored with in-line thermometer

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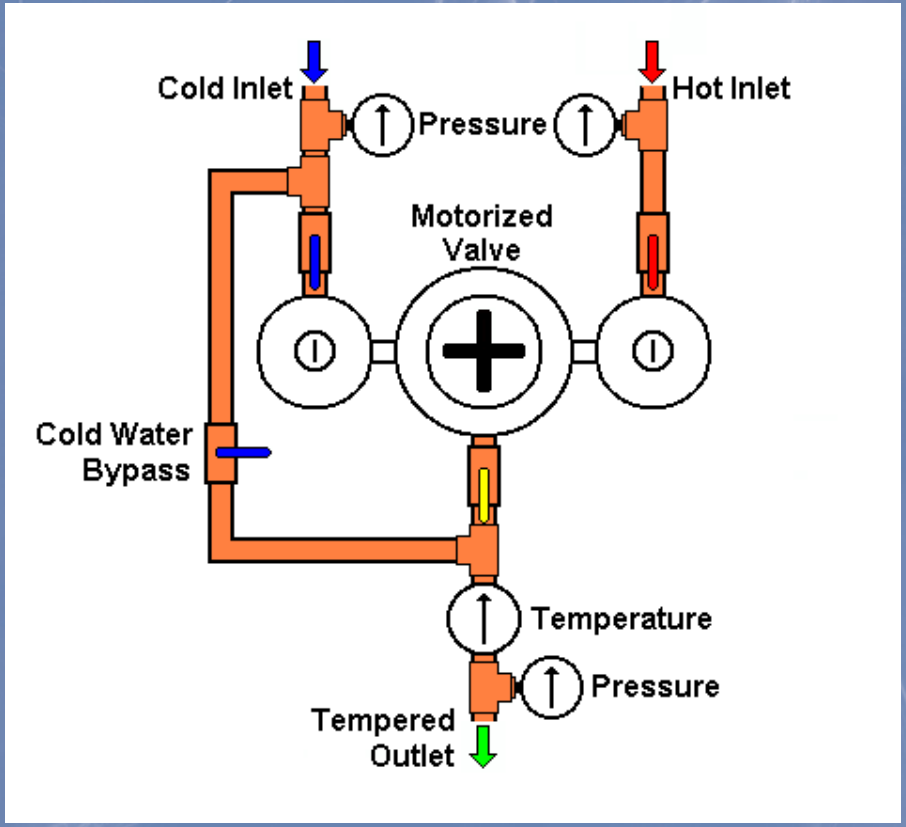
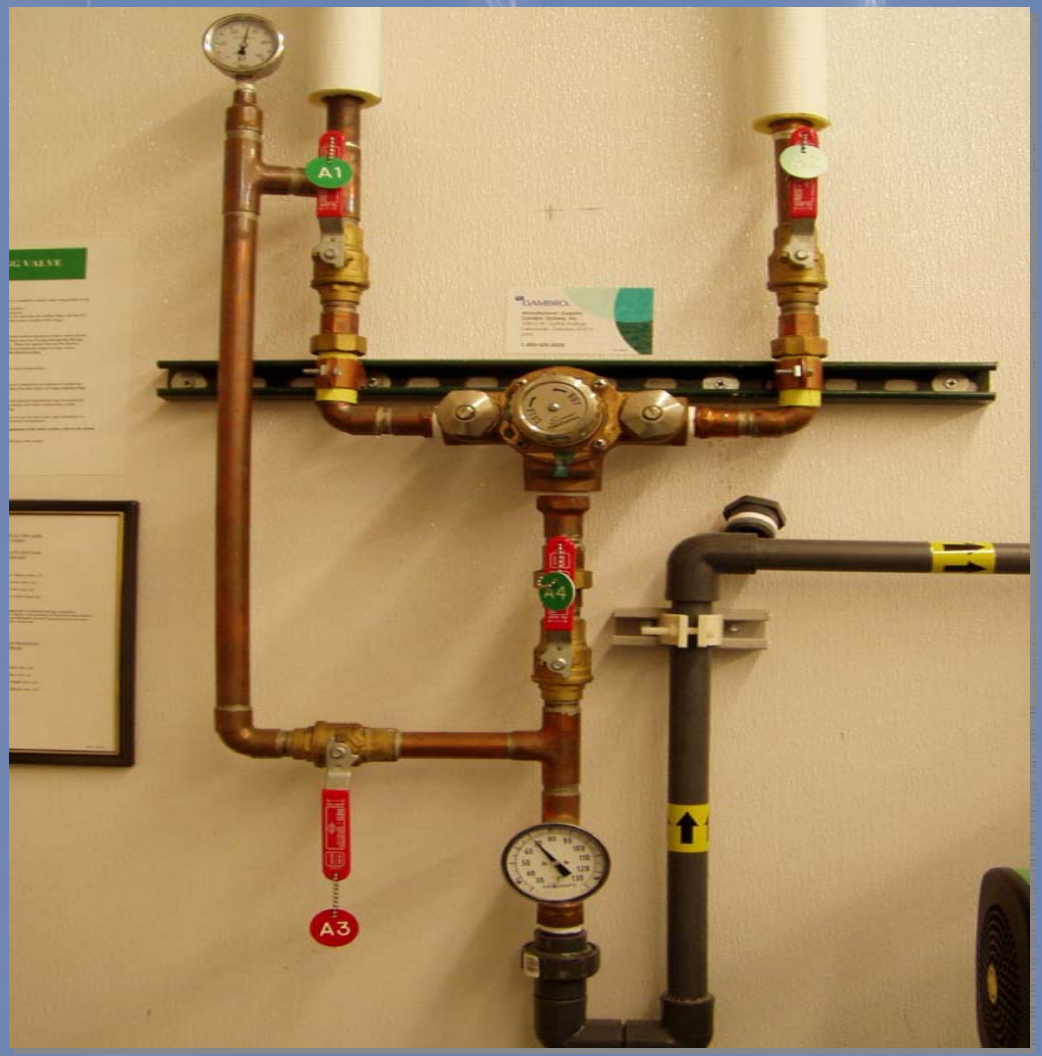
BLENDING VALVE DIAGRAM



BLENDING VALVE



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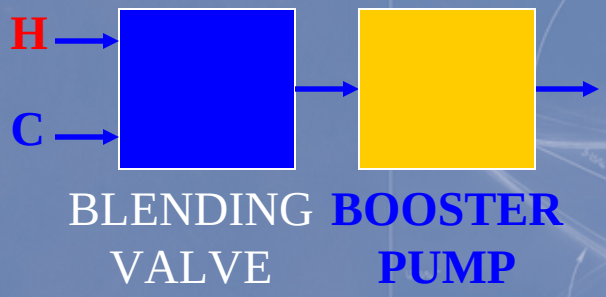
PRETREATMENT DIAGRAM
BOOSTER PUMP



BOOSTER PUMP

- Raises inlet water to preset pressure
  - Stable RO operation
  - Adequate backwash & regeneration cycles
  - Eliminate wide pressure fluctuations
- Monitoring
  - In-line pressure gauges

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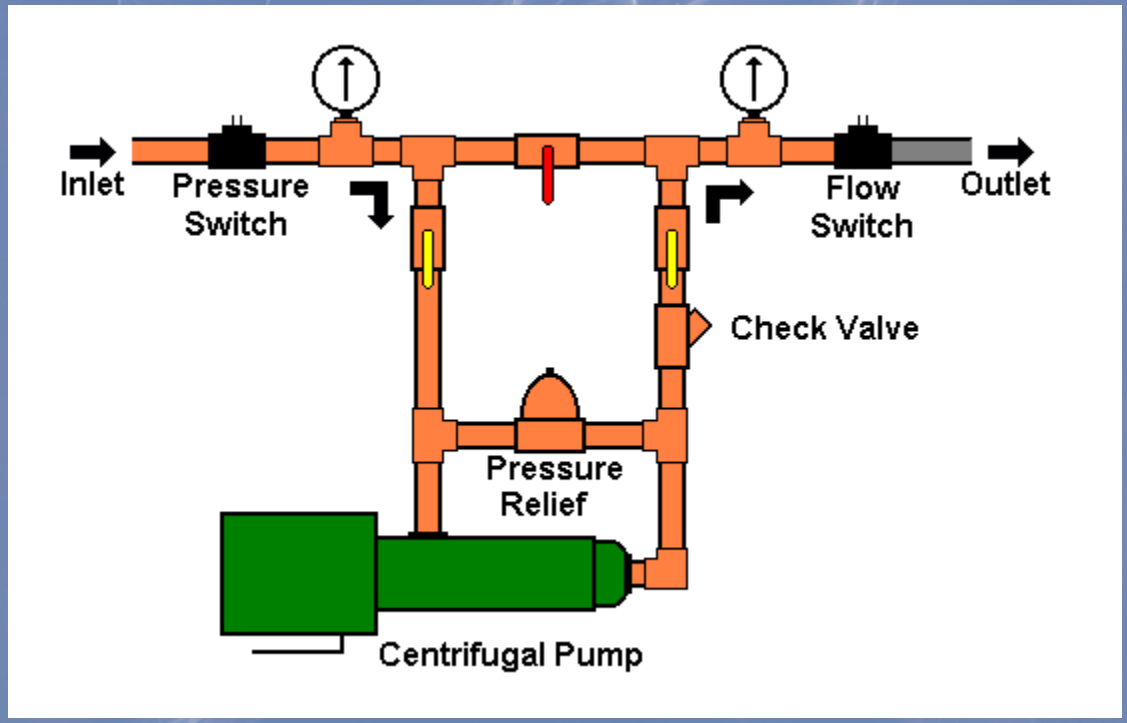
BOOSTER PUMP DIAGRAM



BOOSTER PUMP

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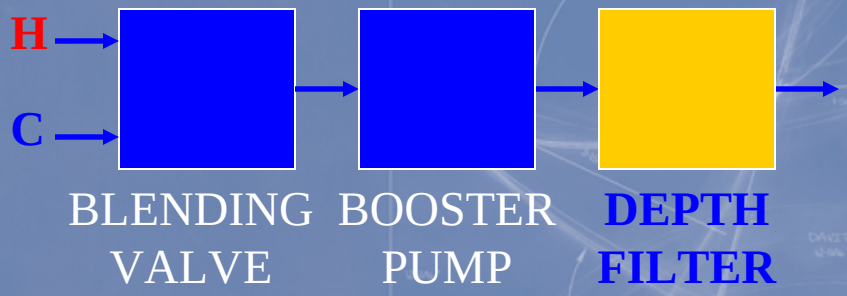
PRETREATMENT DIAGRAM
DEPTH FILTER



MULTIMEDIA DEPTH FILTER

- Particle removal to 10 microns
- Backwashable
- Large capacity
- Monitoring
  - In-line pressure gauges
  - Timer setting

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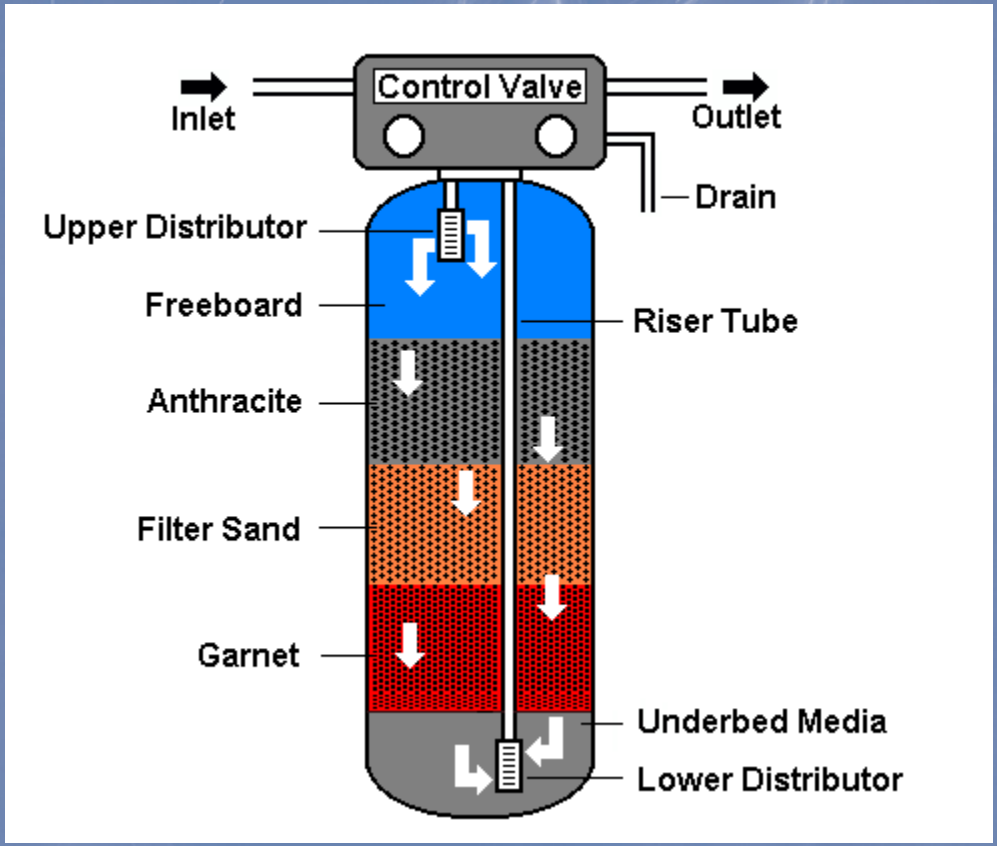
MULTIMEDIA DEPTH FILTER DIAGRAM



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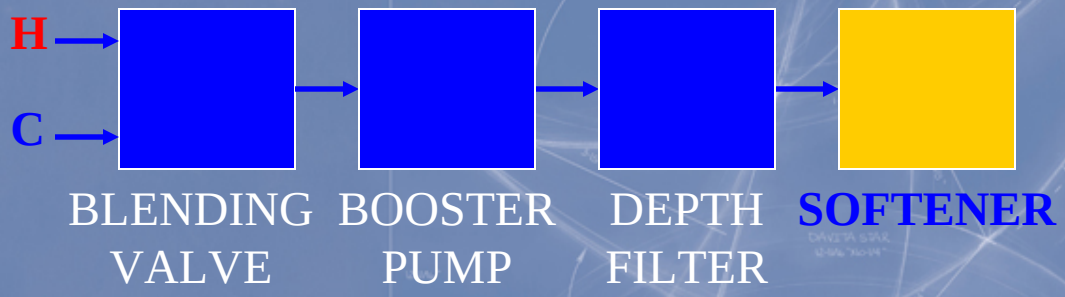
MULTIMEDIA DEPTH FILTER

PRETREATMENT DIAGRAM
SOFTENER



WATER SOFTENER

- Ion exchange process
  - Removes calcium & magnesium “hardness” ions
  - Adds “soft” sodium ions
- Monitoring
  - Hardness test kits/strips
  - Timer setting
  - Brine tank salt level

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WATER SOFTENER
INSTALLATION REQUIREMENTS

- Capacity ≥ 1 day's operation
- Regenerable Softeners
  - Include RO "lockout"
  - Regenerate with pellet salt

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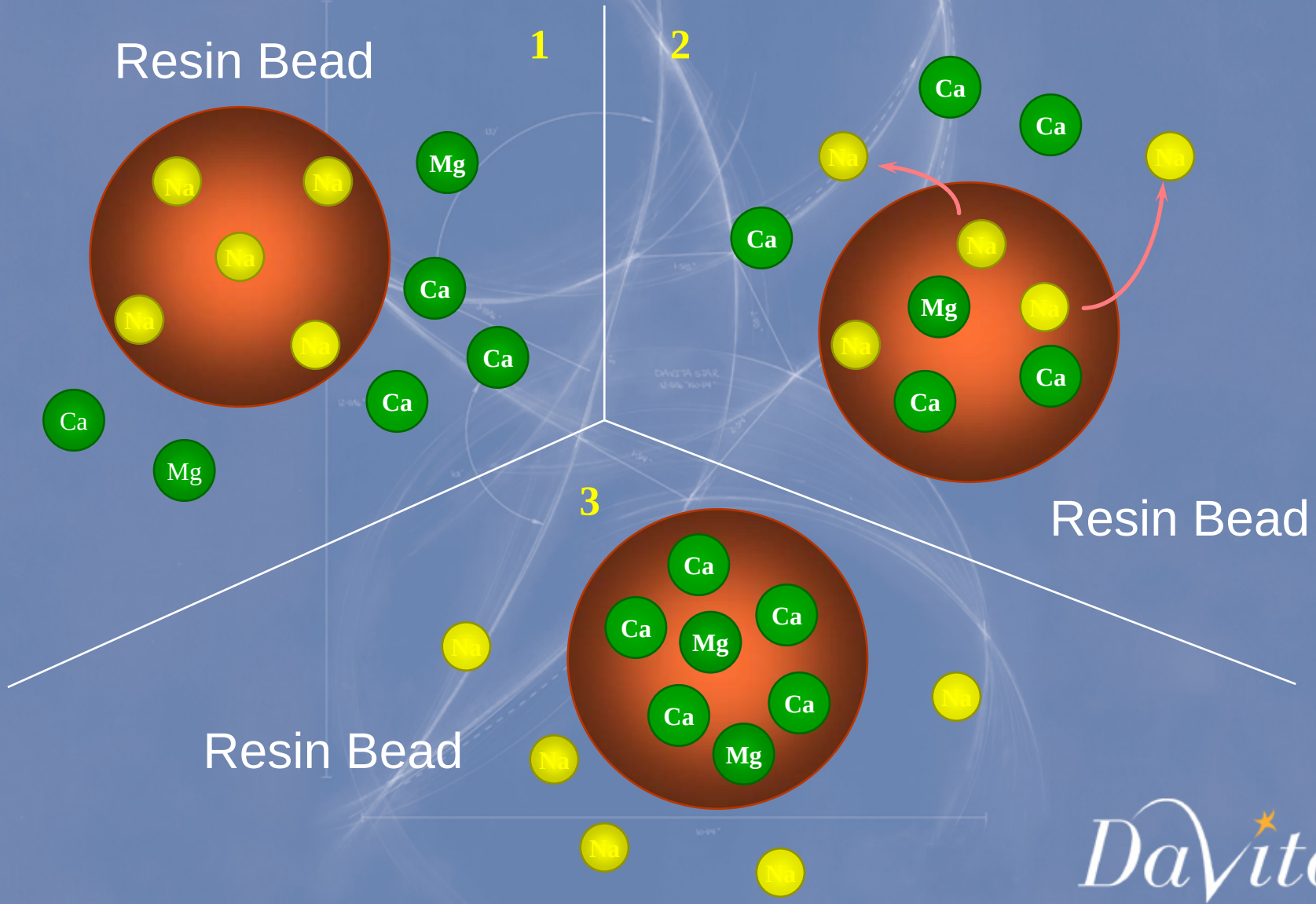
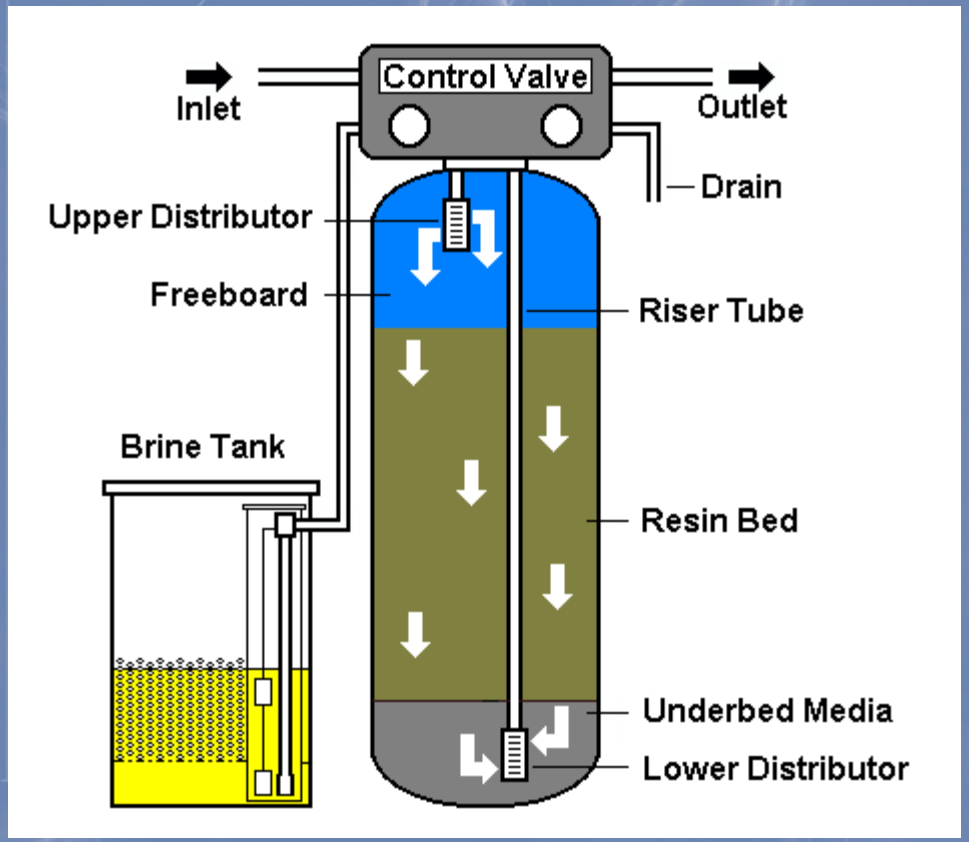
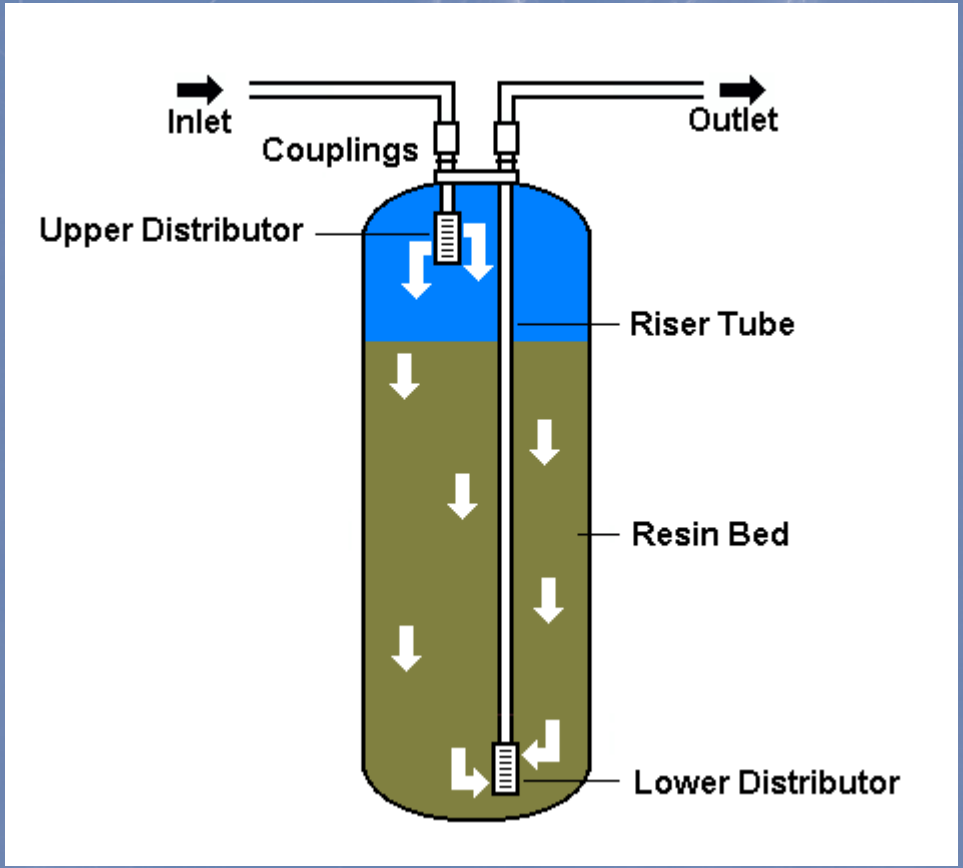
WATER SOFTENER - PRINCIPLE OF ION EXCHANGE



PERMANENT SOFTENER DIAGRAM



EXCHANGE SOFTENER DIAGRAM



WATER SOFTENER

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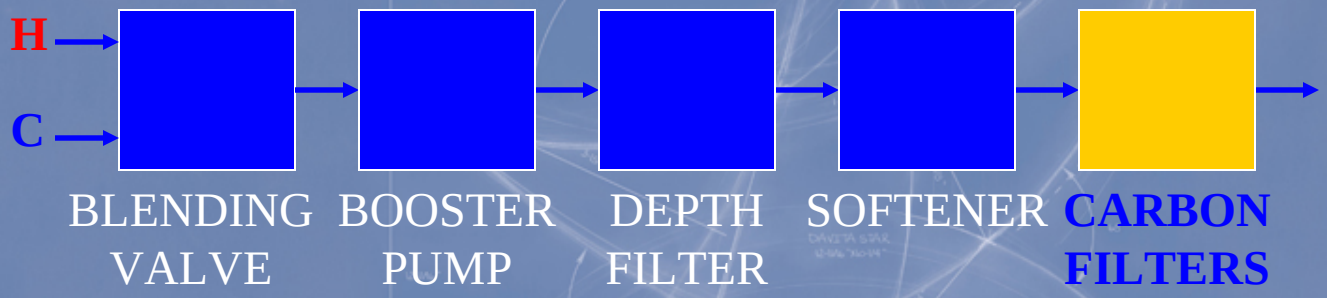
PRETREATMENT DIAGRAM
CARBON FILTERS



CARBON FILTERS

- Adsorption Process
  - Chloramine Broken down & adsorption (patient protection)
  - Free chlorine adsorption (RO protection)
- Monitoring
  - Test kits/strips
  - Timer setting
  - In-line pressure gauges

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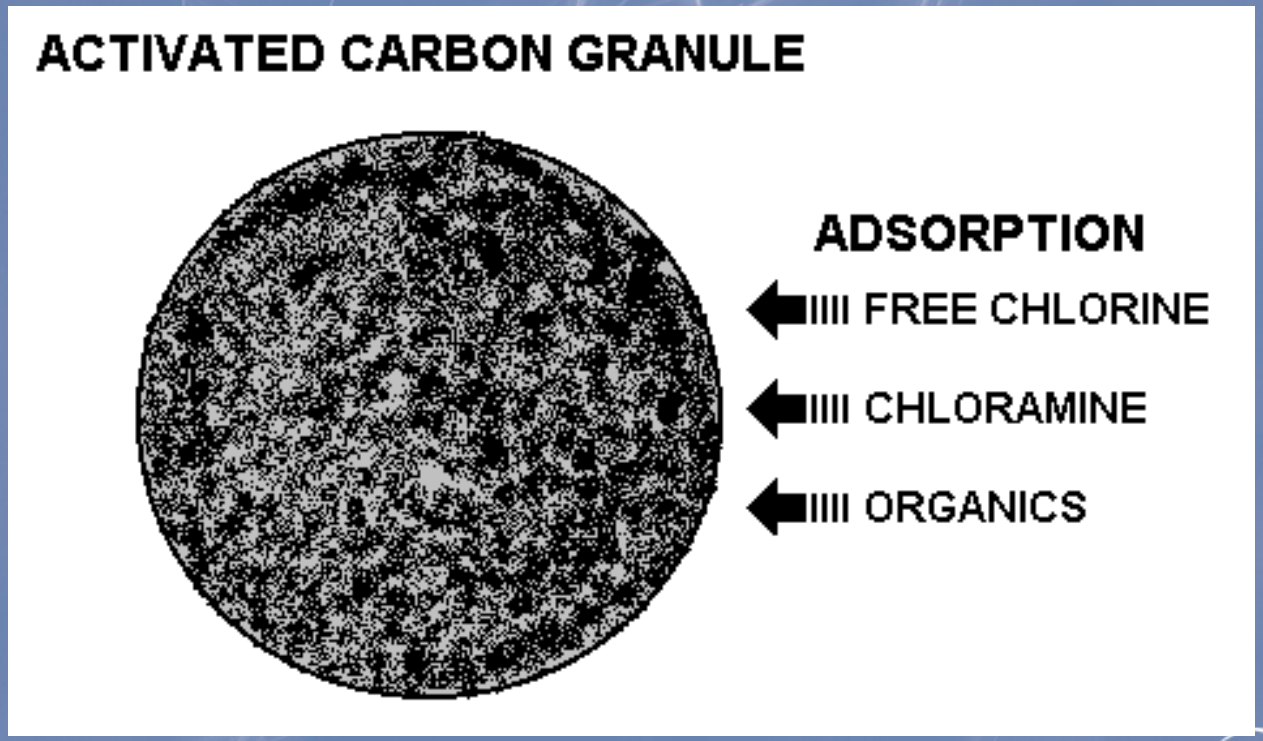
CARBON ADSORPTION



CARBON FILTERS
INSTALLATION REQUIREMENTS

- Series-connected pairs
- Sample taps after primary & secondary filters
- RO “lockout” on backwashable filters
- Include accidental bypass protection

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CARBON FILTERS
SIZING REQUIREMENTS

- Empty Bed Contact Time (EBCT)
  - EBCT, min = (GAC Volume, ft^3 x 7.48)/Flow, gpm
- EBCT calculated for all beds combined
  - Minimum EBCT ≥ **10 minutes**

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CARBON FILTERS
MEDIA SELECTION

- Granular activated carbon (GAC)
- Iodine number ≥ 900
- Mesh size 12 x 40 or smaller
- Coal-based carbon should be acid-washed

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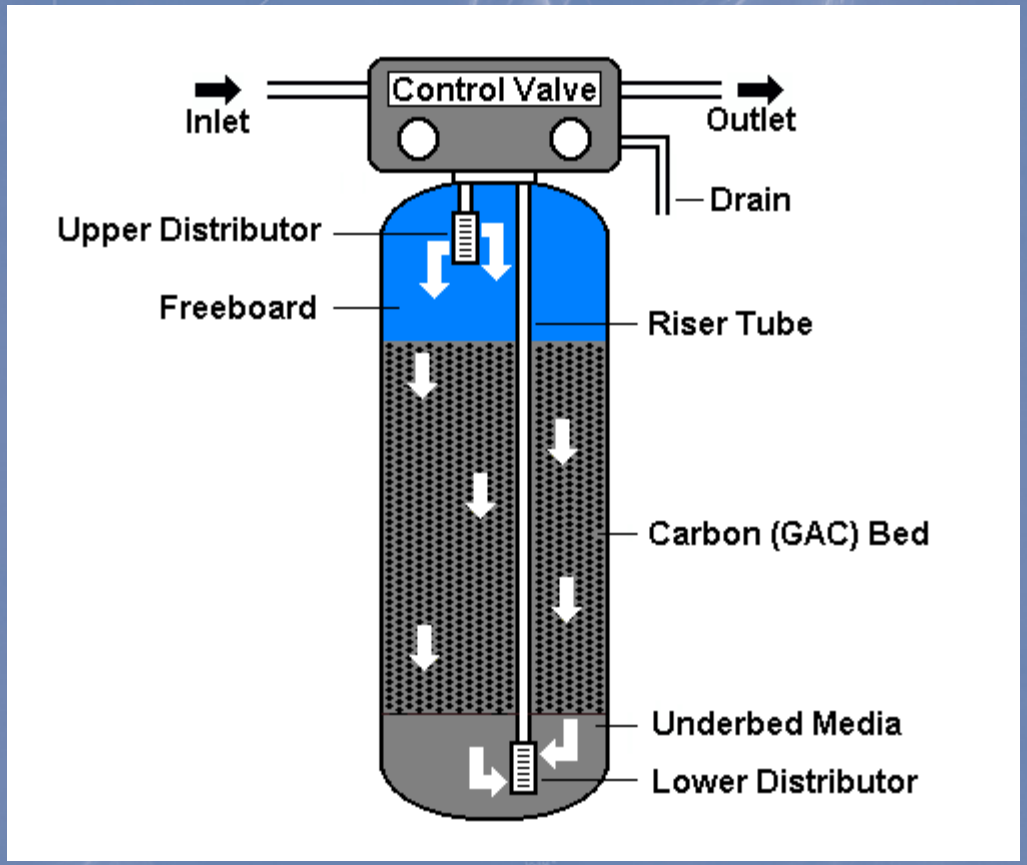
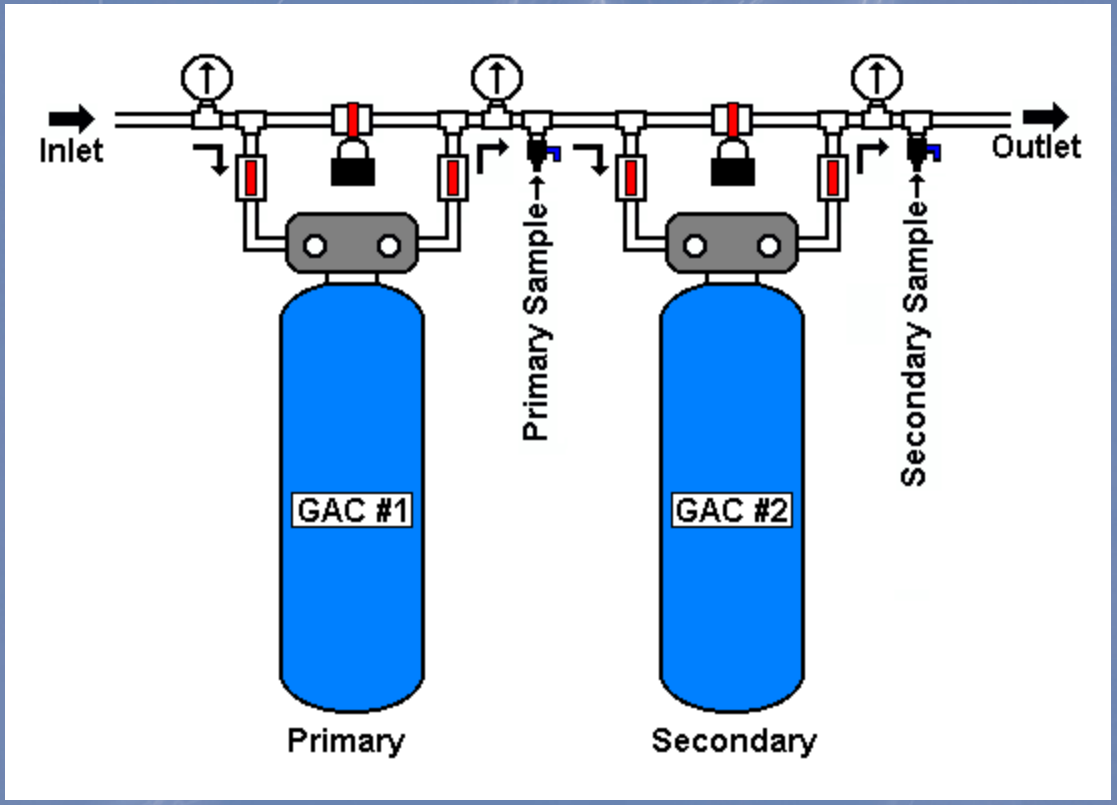
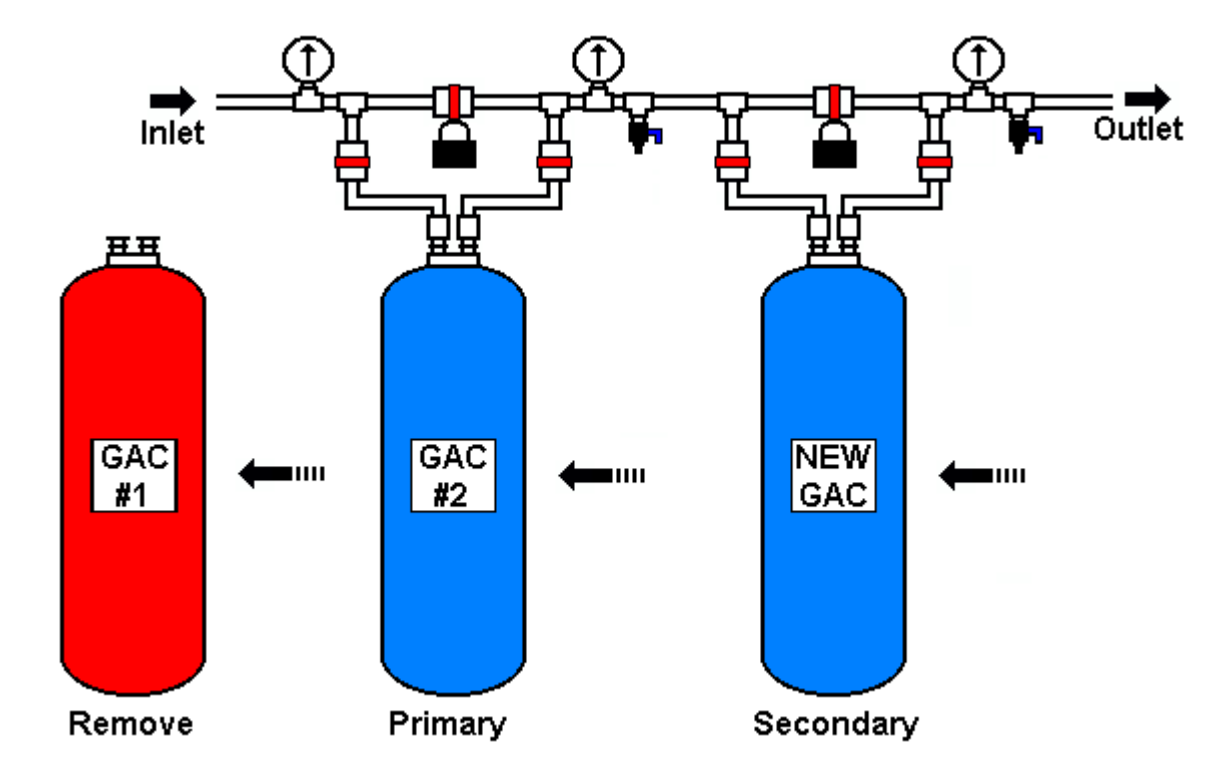
BACKWASHABLE CARBON FILTER DIAGRAM



PAIRED BACKWASHABLE CARBON FILTERS



EXCHANGE CARBON FILTER ROTATION



CARBON FILTERS
SERIES CONFIGURATION

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CARBON FILTERS
SERIES-PARALLEL CONFIGURATION

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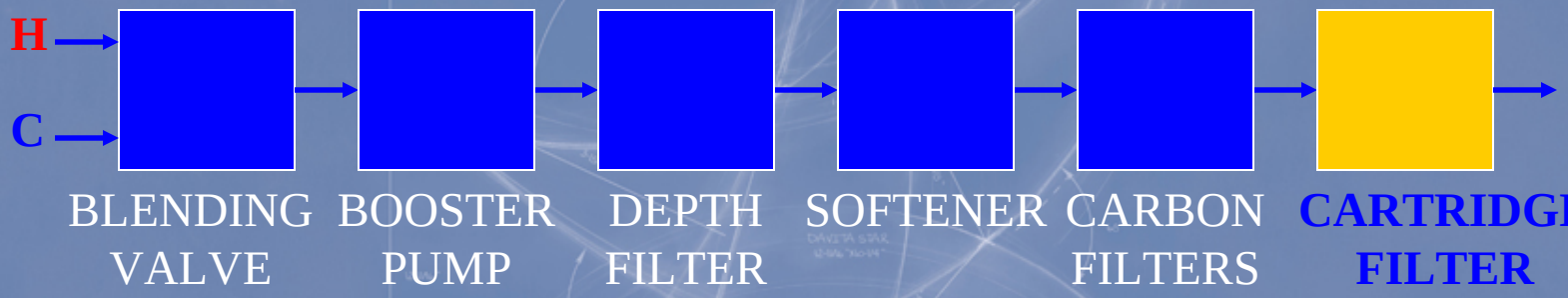
PRETREATMENT DIAGRAM
CARTRIDGE FILTER



CARTRIDGE FILTER

- Particle removal to 5 microns or smaller
- Pre-RO installation
- Opaque cartridge housings mandatory
- Remove particles of 5 microns or smaller
- Monitoring
  - In-line pressure gauges

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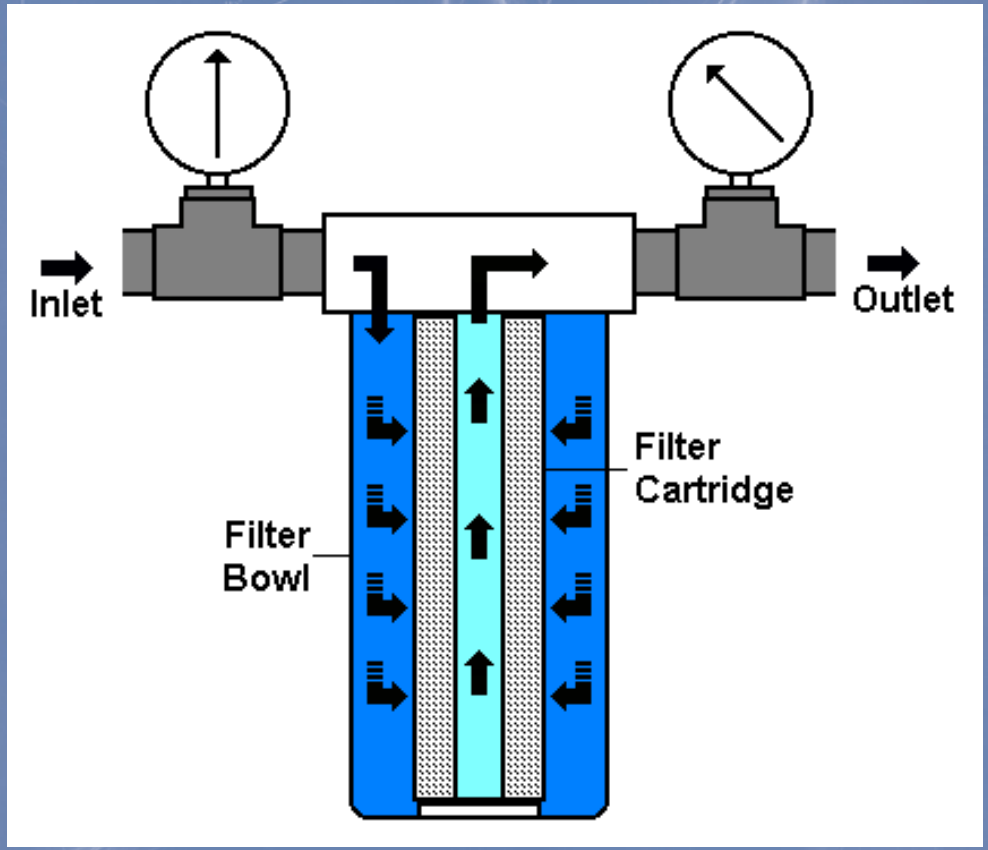
CARTRIDGE FILTER DIAGRAM



CARTRIDGE FILTER

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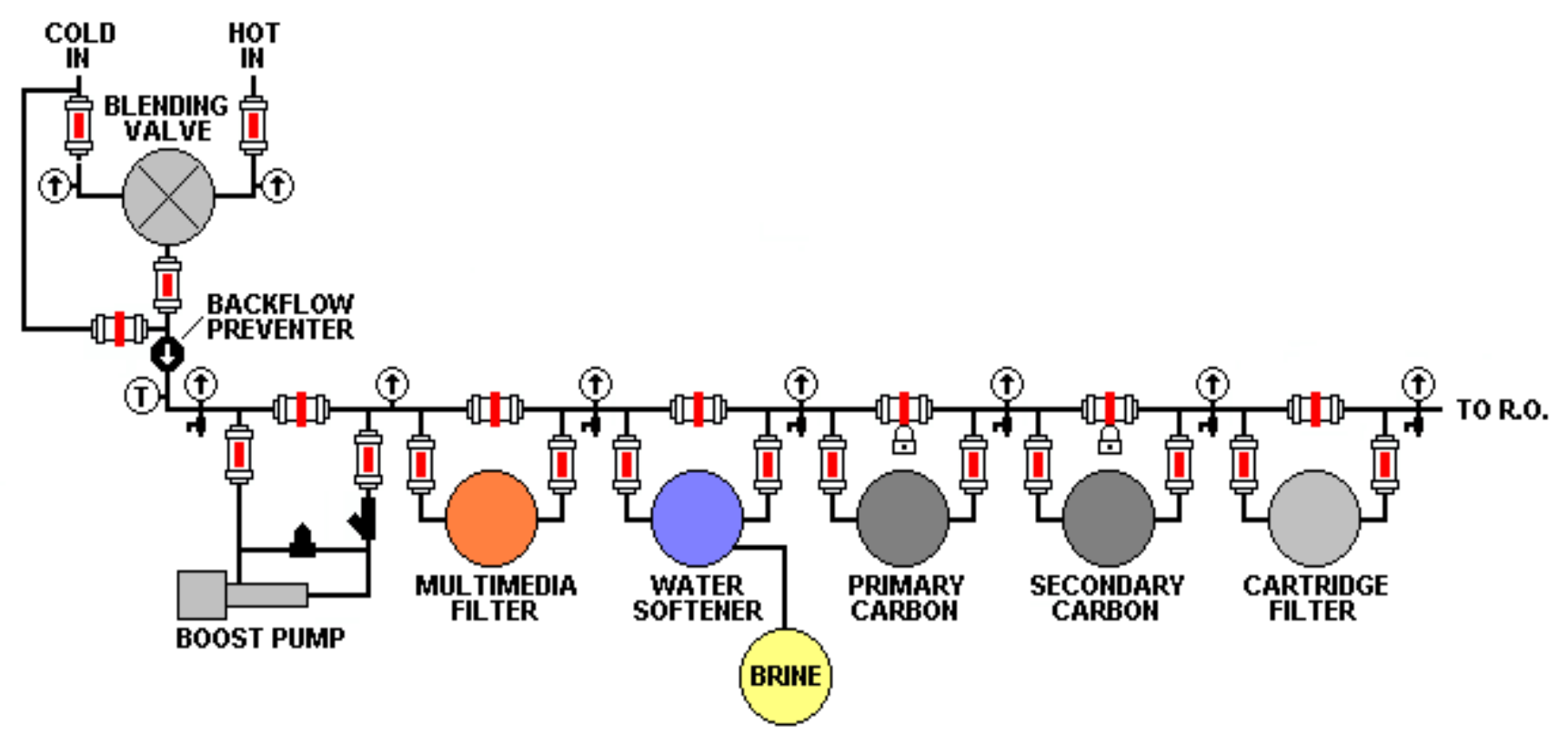
TYPICAL PRETREATMENT SYSTEM DIAGRAM



WATER TREATMENT STAGES

Pretreatment

Purification & Distribution

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PURIFICATION PROCESS

- Remove inorganic & organic substances
  - Inorganics (chemicals)
  - Bacteria
  - Bacterial endotoxin
- Monitoring
  - In-line monitors & gauges
  - Lab testing for chemicals, bacteria & endotoxin

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PURIFICATION COMPONENTS

- Reverse Osmosis (RO)
- Deionization (DI) + Ultrafiltration (UF)

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REVERSE OSMOSIS

- Pump & membrane system *reverses* osmotic flow to produce purified water
- Removes chemicals, bacteria & endotoxin
- Monitoring
  - In-line conductivity monitors
  - In-line flow & pressure gauges
  - Lab testing for chemicals, bacteria & endotoxin

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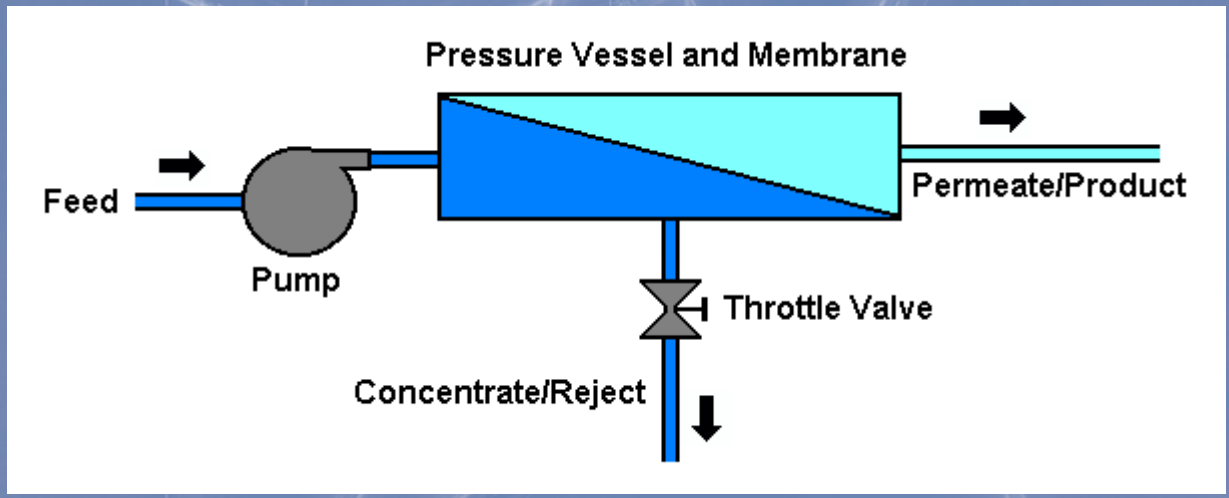
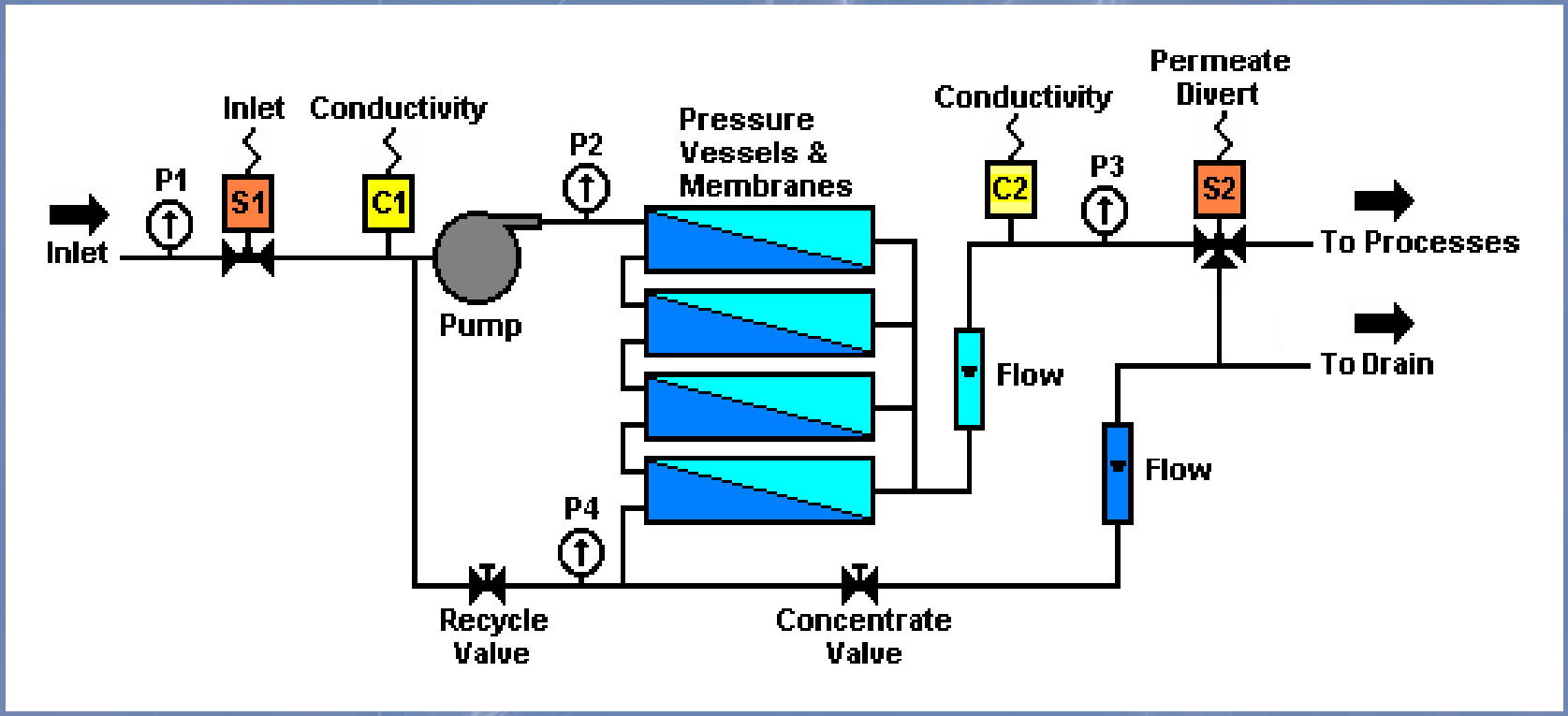
BASIC RO MACHINE DIAGRAM



TYPICAL RO MACHINE DIAGRAM



RO SYSTEM
CONVENTIONAL RO

RO SYSTEM
CWP

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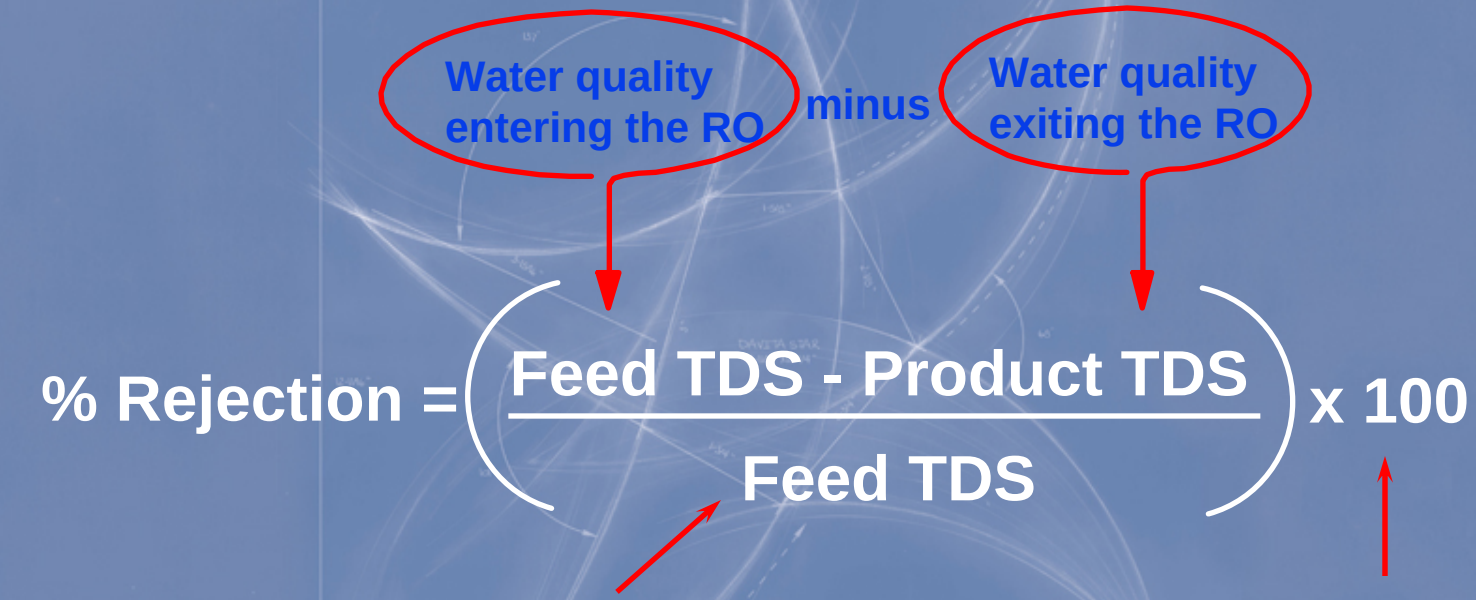
PERCENT REJECTION



Example:	**400 - 10 = 390**
Feed TDS = 400	**390 ÷ 400 = 0.975**
Product TDS = 10	**0.975 x 100 = 97.5%**

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DEIONIZATION

- Ion exchange process removes both cations & anions
- DANGEROUS when exhausted
- Often increase bacterial & endotoxin levels
- Monitoring
  - Mandatory in-line resistivity monitor w/alarms
  - Lab testing for chemicals

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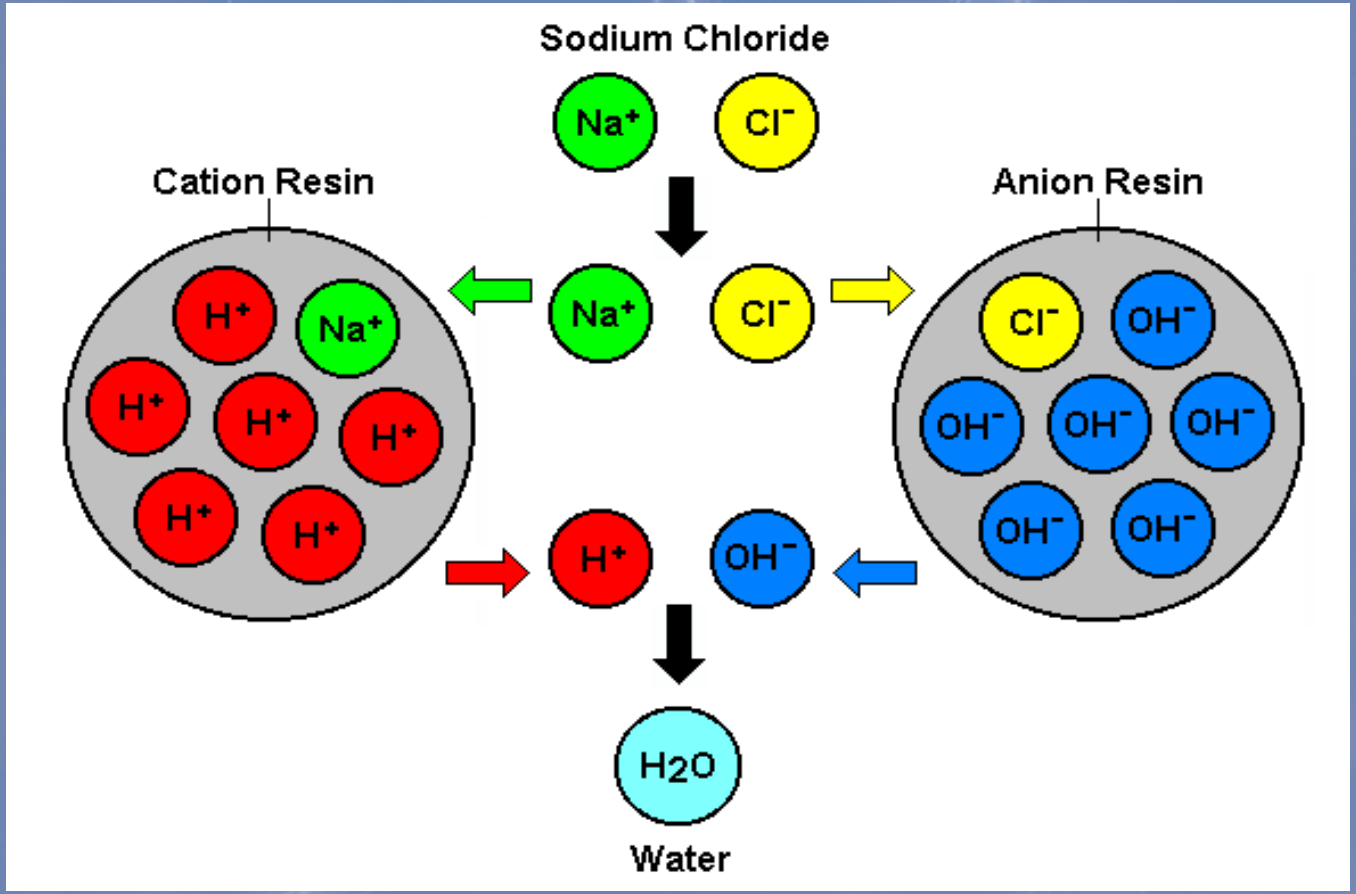
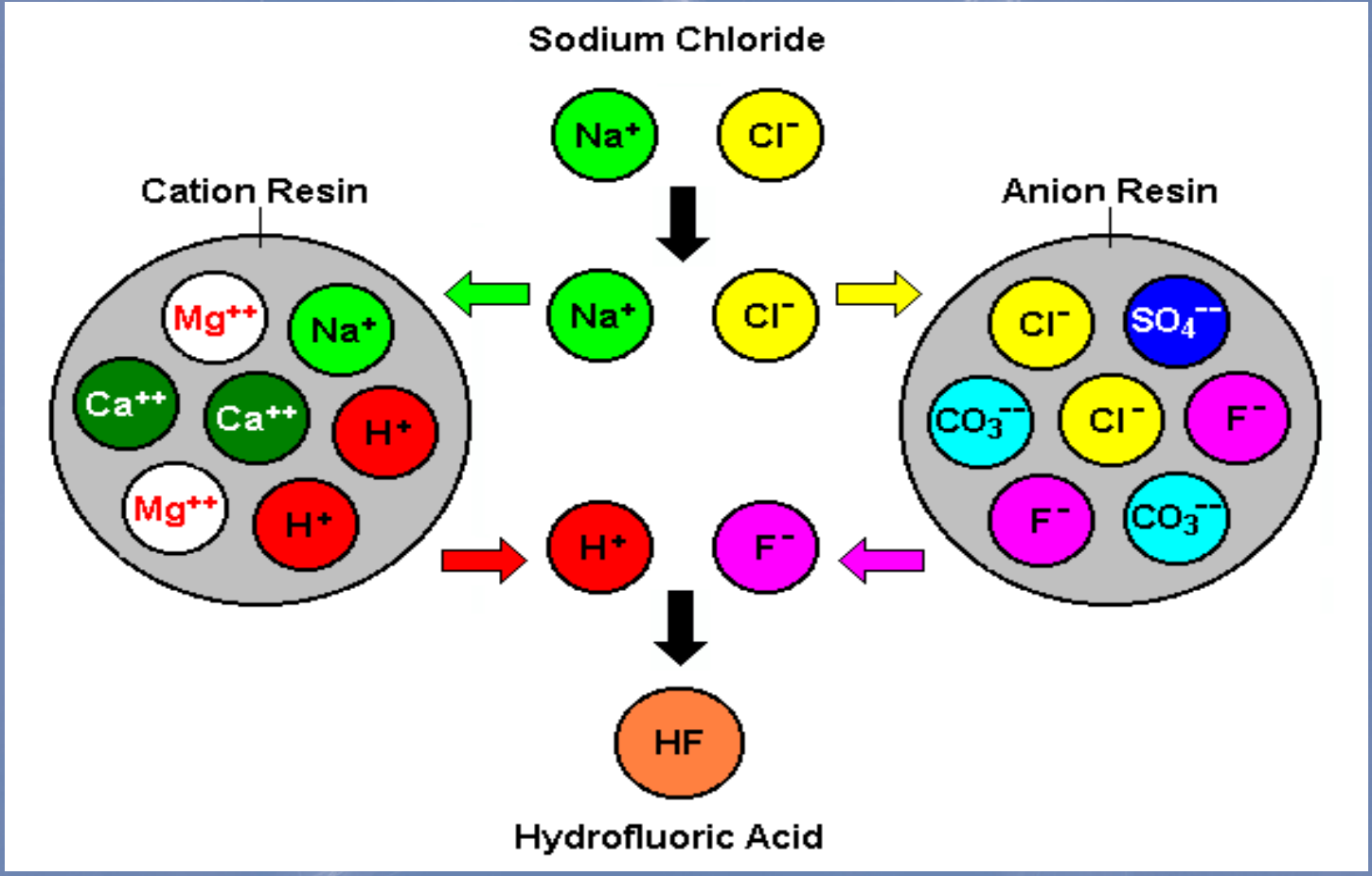
DEIONIZATION

ION EXCHANGE PROCESS

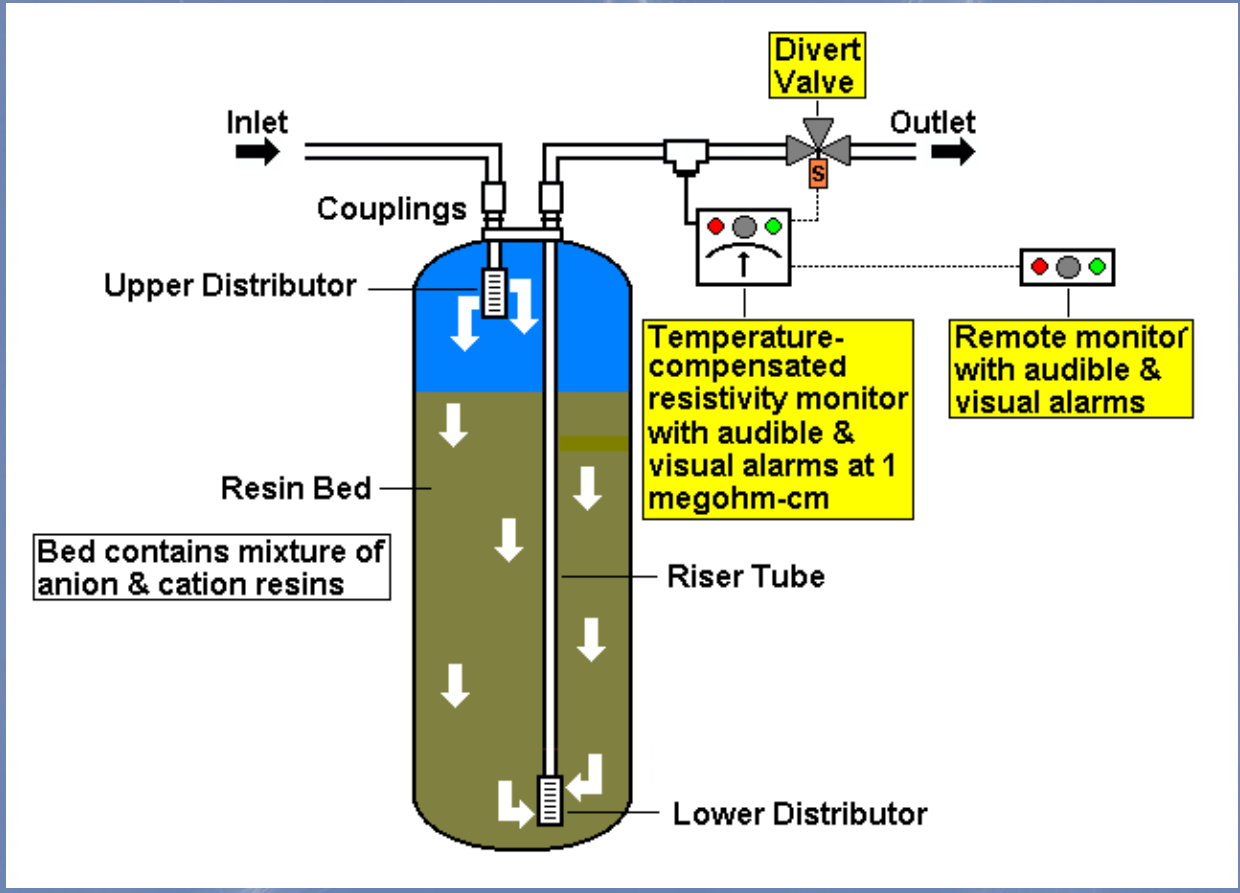


DANGEROUS

DEIONIZER EXHAUSTION



“MIXED-BED” DI & MONITORING SYSTEM



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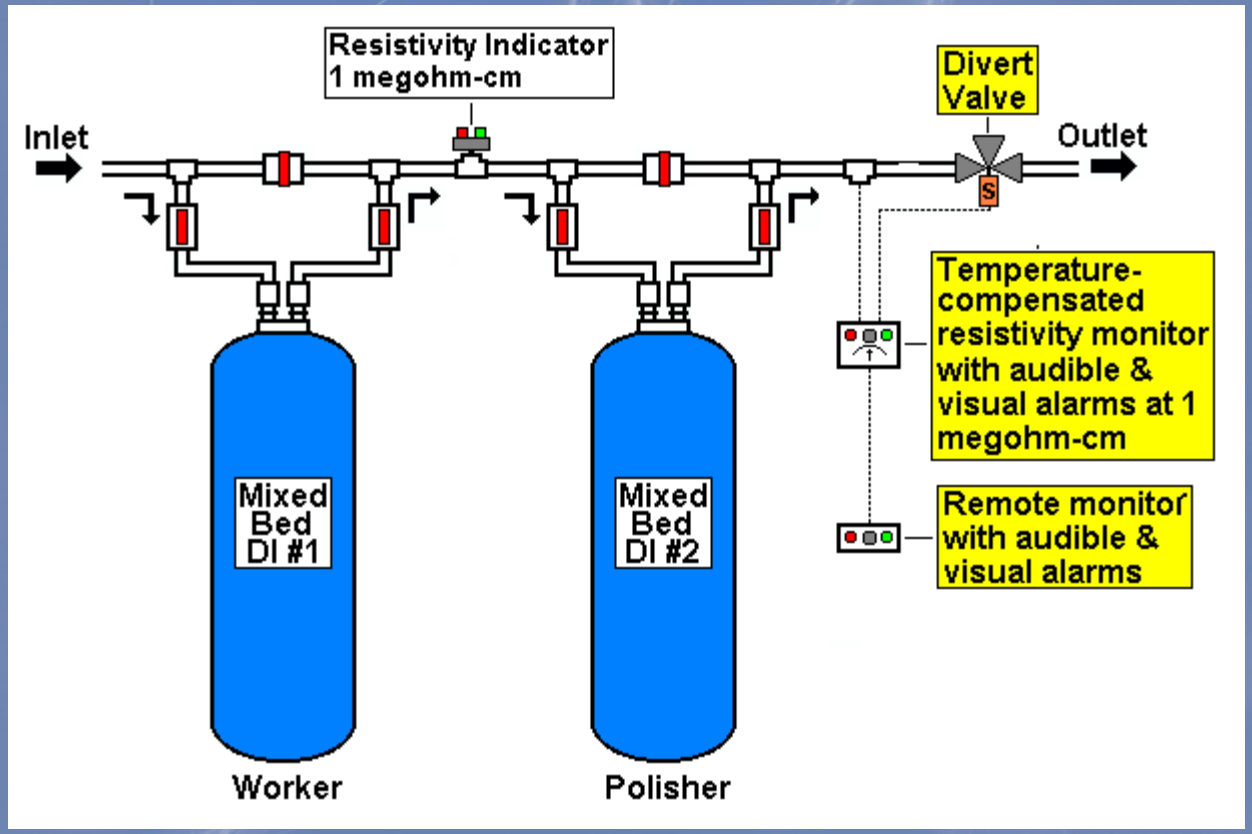
TYPICAL WORKER-POLISHER MIXED-BED DI INSTALLATION



DEIONIZATION (DI) SYSTEM

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DEIONIZATION (DI) SYSTEM AUTOMATED DIVERT TO DRAIN

ULTRAFILTRATION

- Filtration process removes bacteria & endotoxin
- Required downstream of DI
- Required downstream of Ultraviolet Irradiators (UV)
- Monitoring
  - In-line pressure gauges
  - Lab testing for bacteria & endotoxin

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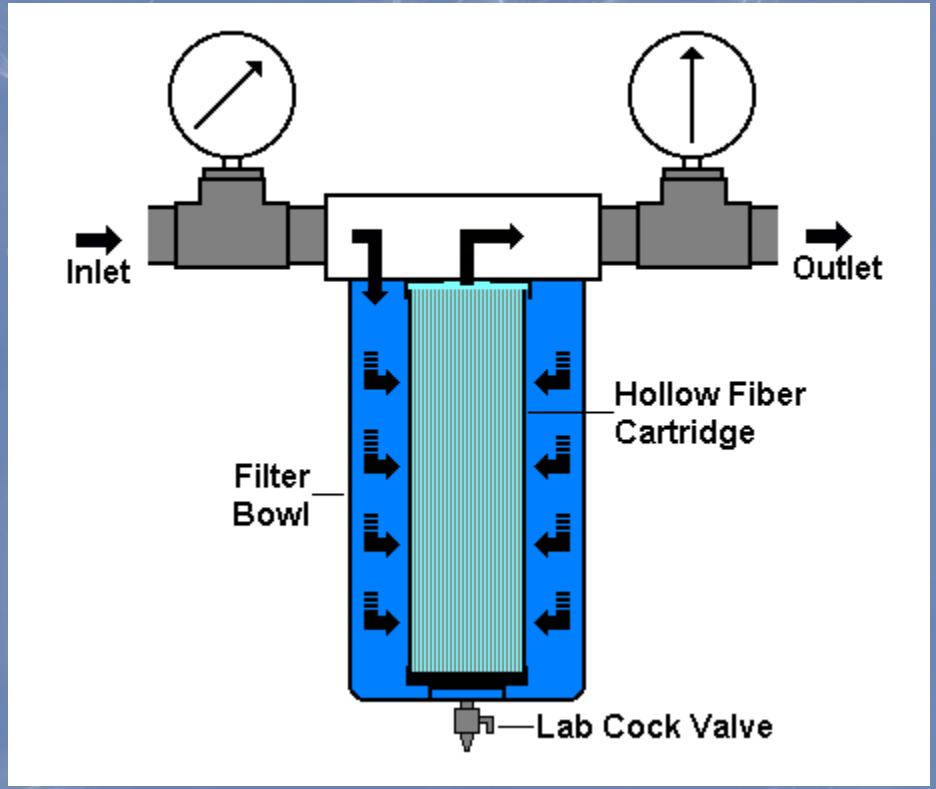
HOLLOW FIBER ULTRAFILTER DIAGRAM



ENDOTOXIN FILTER

STORAGE TANK AND RECIRCULATION PUMP

- Water Storage tanks are typically used in systems which consume large amounts of water for procedures such as reuse.
- Water Storage tanks are not used in all water treatment systems.
- Water Storage tank systems have the following characteristics:
  - •Conical bottom, sealed storage tank
  - •Recirculation pump to circulate the water through the distribution loop
  - •Level and alarm switches to control the RO Unit and the recirculation pump
  - •Bacteria filter on the tank overflow

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WATER STORAGE TANK AND RECIRCULATION PUMP

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ULTRAVIOLET (UV) LIGHT

- UV lights are used to kill bacteria
- UV light is produced by a mercury vapor lamp which emits light through a quartz sleeve into the water passing through the light. Bacteria exposed to the light will be killed.
- Since UV lights kill bacteria, they can produce endotoxins and must be followed by either RO or endotoxin filters.
- UV lights are incorporated into the water treatment system as specified by the manufacturer and are not required on all water treatment systems.

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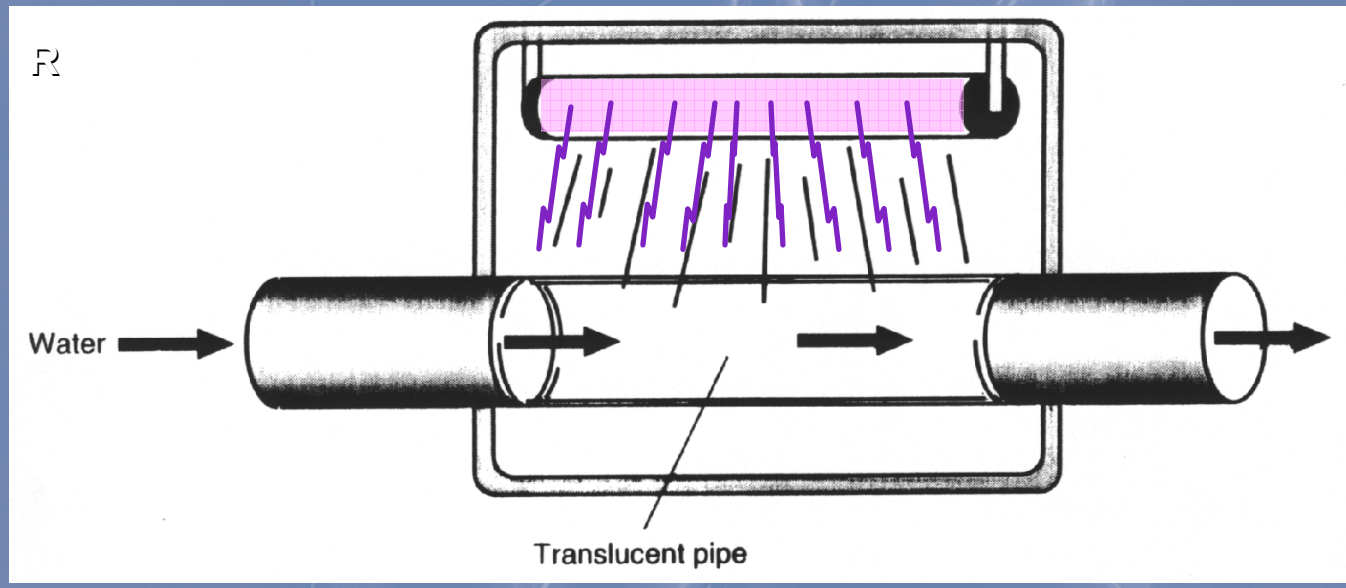
ULTRAVIOLET (UV) LIGHT

Water does not contact the light itself

UV light shines through a quartz tube



UV light kills most remaining bacteria

Dead bacteria produce endotoxins

If a UV light is present - must be followed by an endotoxin filter

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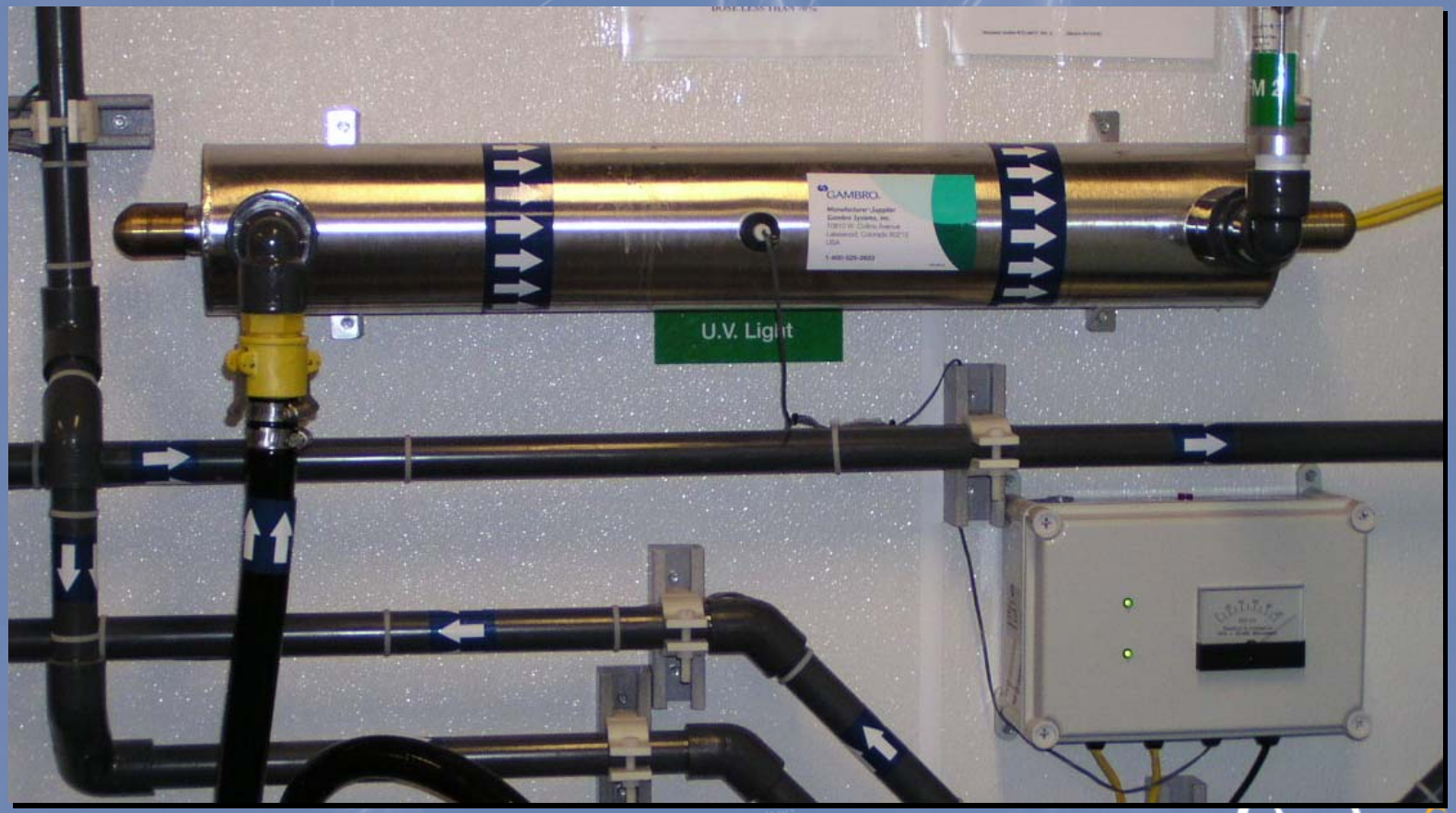
ULTRAVIOLET (UV) LIGHT AND RADIANCE MONITOR



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OTHER SYSTEM COMPONENTS

All components on the RO product side of the water treatment system must be composed of inert materials. This means that they will not leach any unwanted materials into the water used for dialysis.

Inert materials used in dialysis systems include:

- **PVC (polyvinylchloride)**
- **Stainless Steel**
- **Glass**

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OTHER SYSTEM COMPONENTS

There are several other system components which are important to the safe and effective operation of your water treatment system. These include, but are not limited to:

- Distribution loop
- Flow Meters
- Pressure Regulators
- Pressure Gauges
- Sample Ports
- Venturi assemblies

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OTHER SYSTEM COMPONENTS

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Questions