Reverse Osmosis (RO) Basics

Presented by Nitin Chauhan of Culligan
(Hall's Water Group)

For ASPE Cleveland Chapter

October 2012

Outline of Topics

I. RO
- Fundamentals of RO
- RO Selection and Design Criteria
- How to size a RO

II. Benefits of Using RO
- Energy Savings
  - Research from DOE (Dept of Energy)
- Other Benefits
- RO for BFW
  - Water Savings
  - Chemical Savings
  - RO Brine Reclaim

Outline of Topics Cont'd

III. Culligan Background

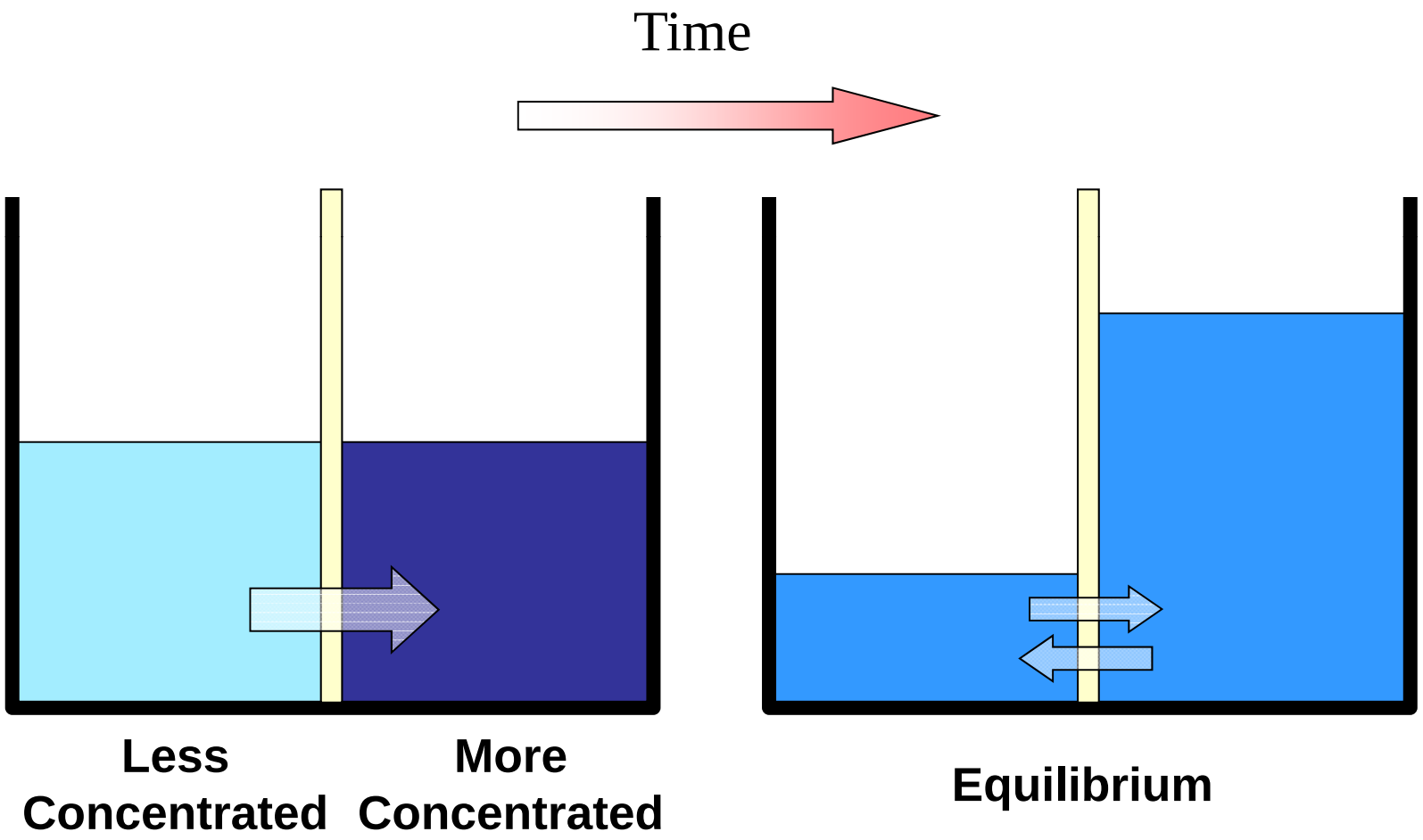
- Culligan International
- Hall's Water Group
- Culligan of Greater Cleveland

Fundamentals of RO

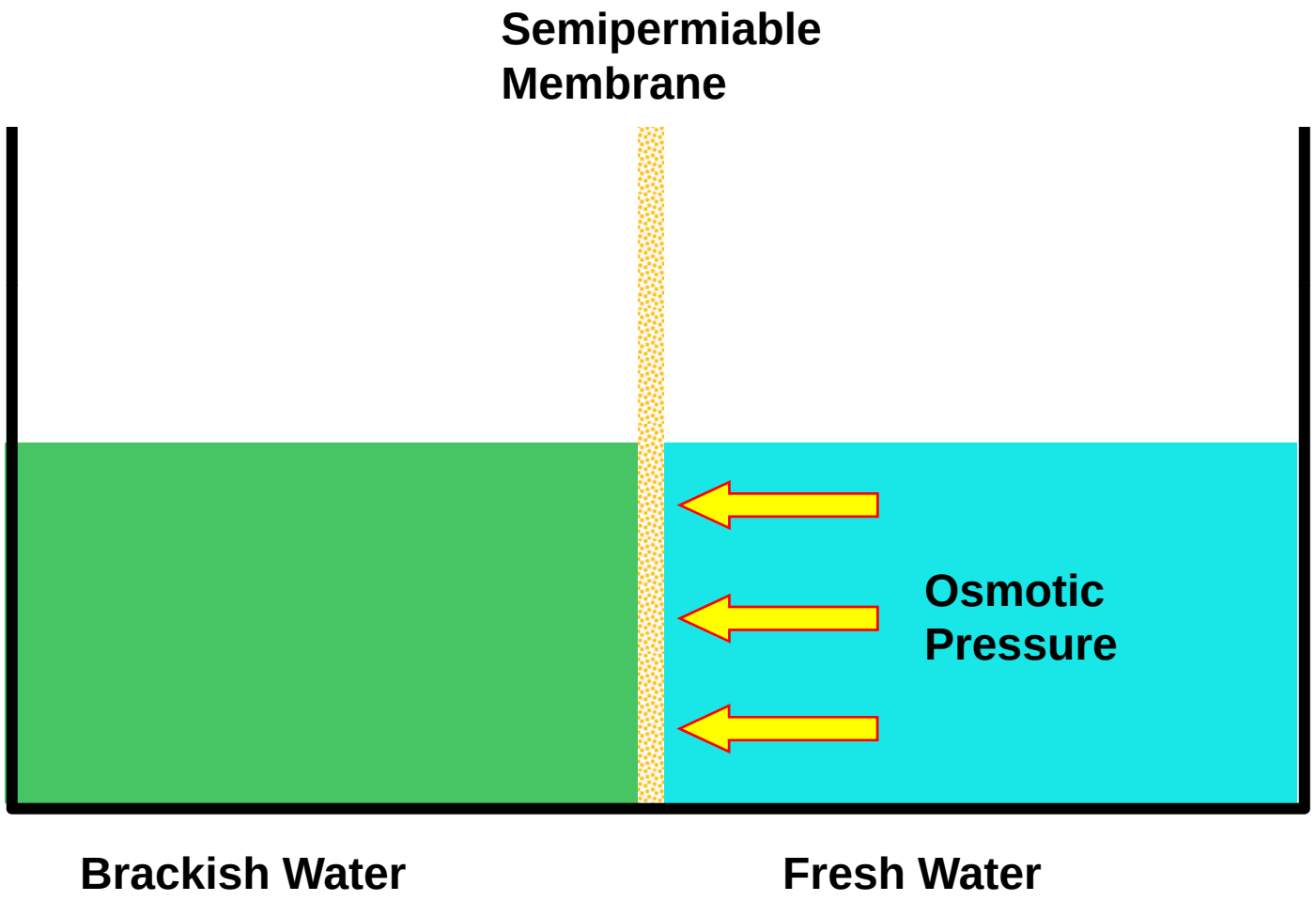
What is Osmosis?

The movement of a solvent (water in our case) across a semi-permeable membrane from a solution of lower concentration to a solution of higher concentration that tends to equalize the concentrations of solute on the both sides of the membrane.

Osmosis



Osmosis in Nature



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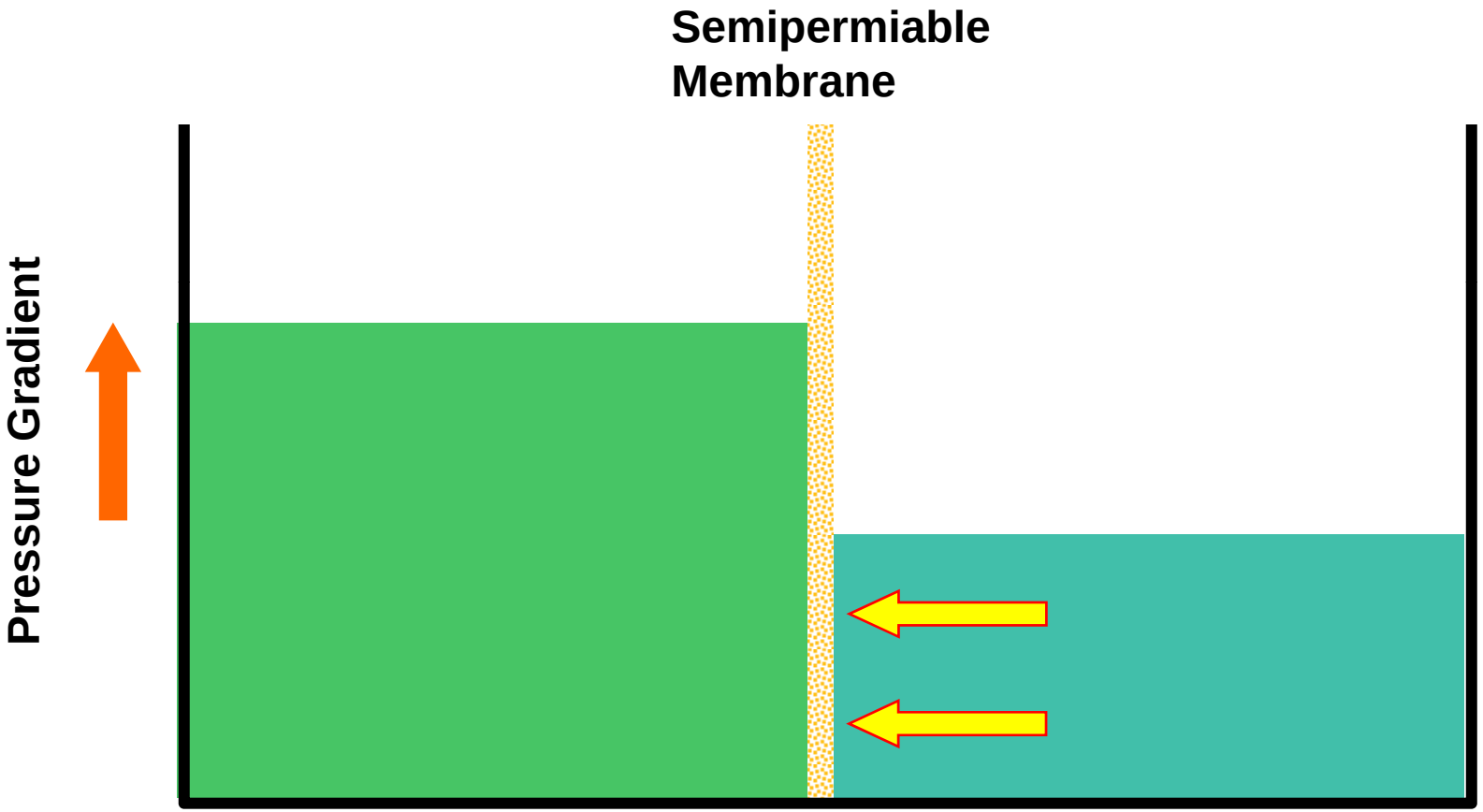
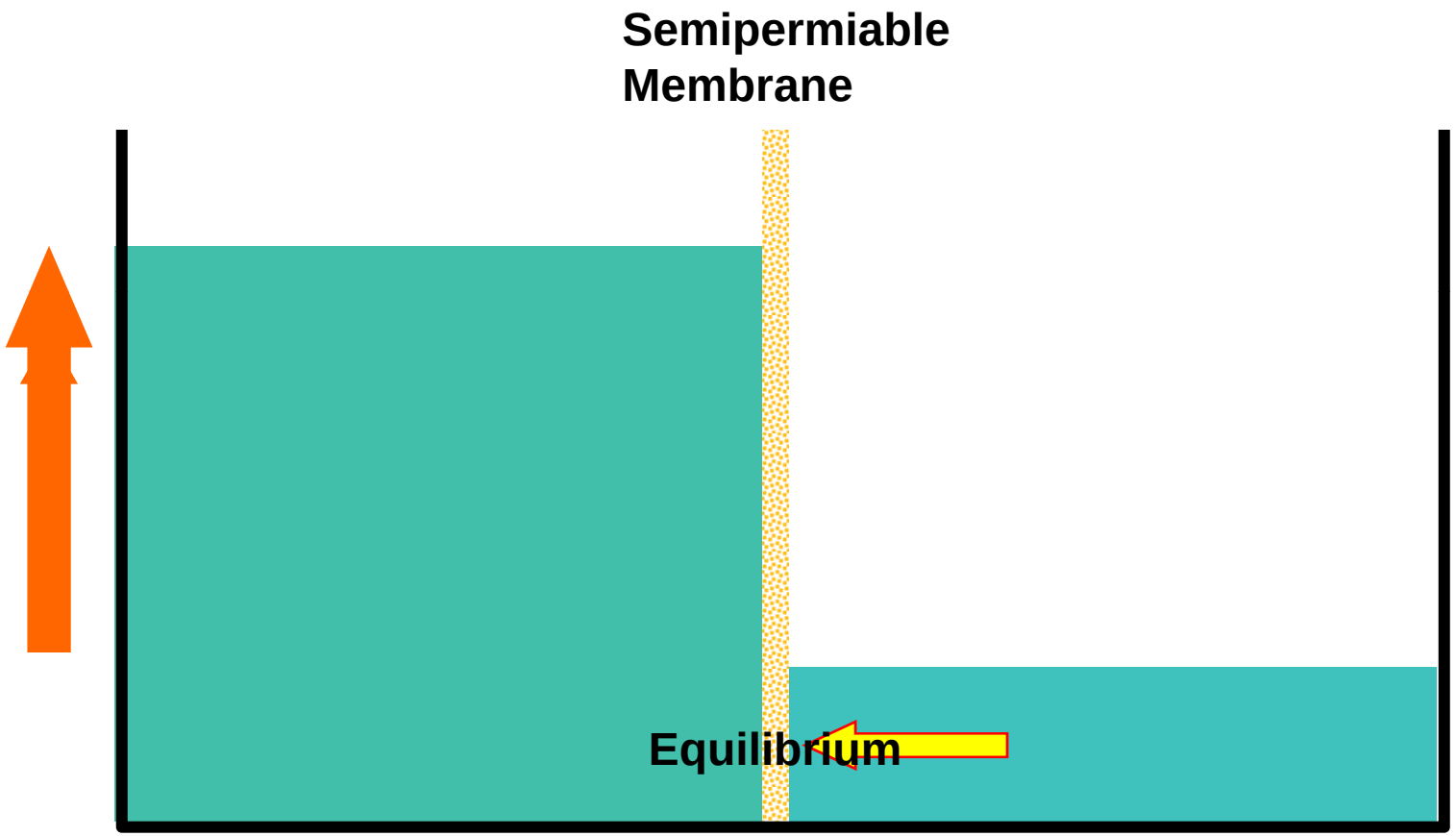
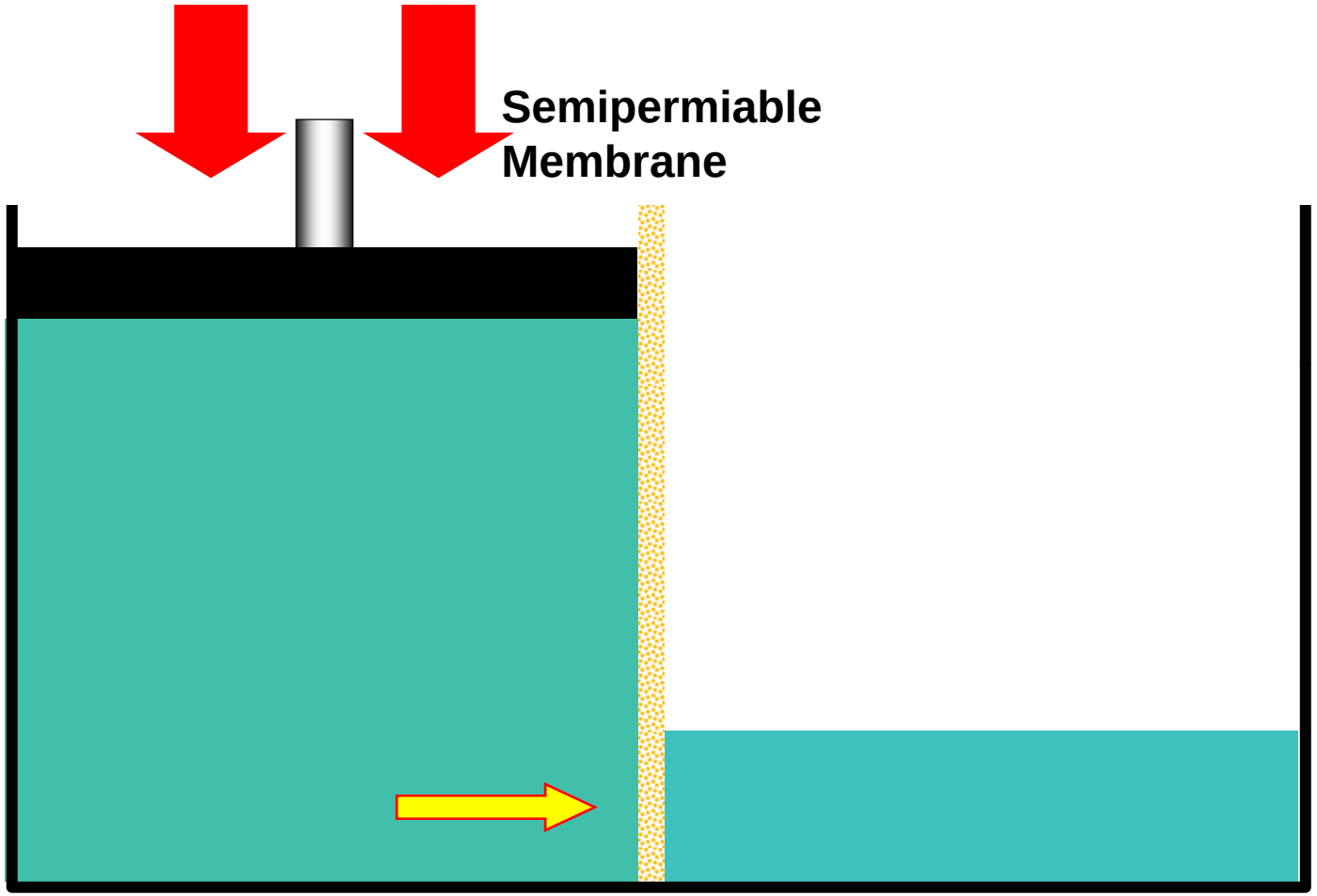


Osmosis in Nature



Reverse Osmosis



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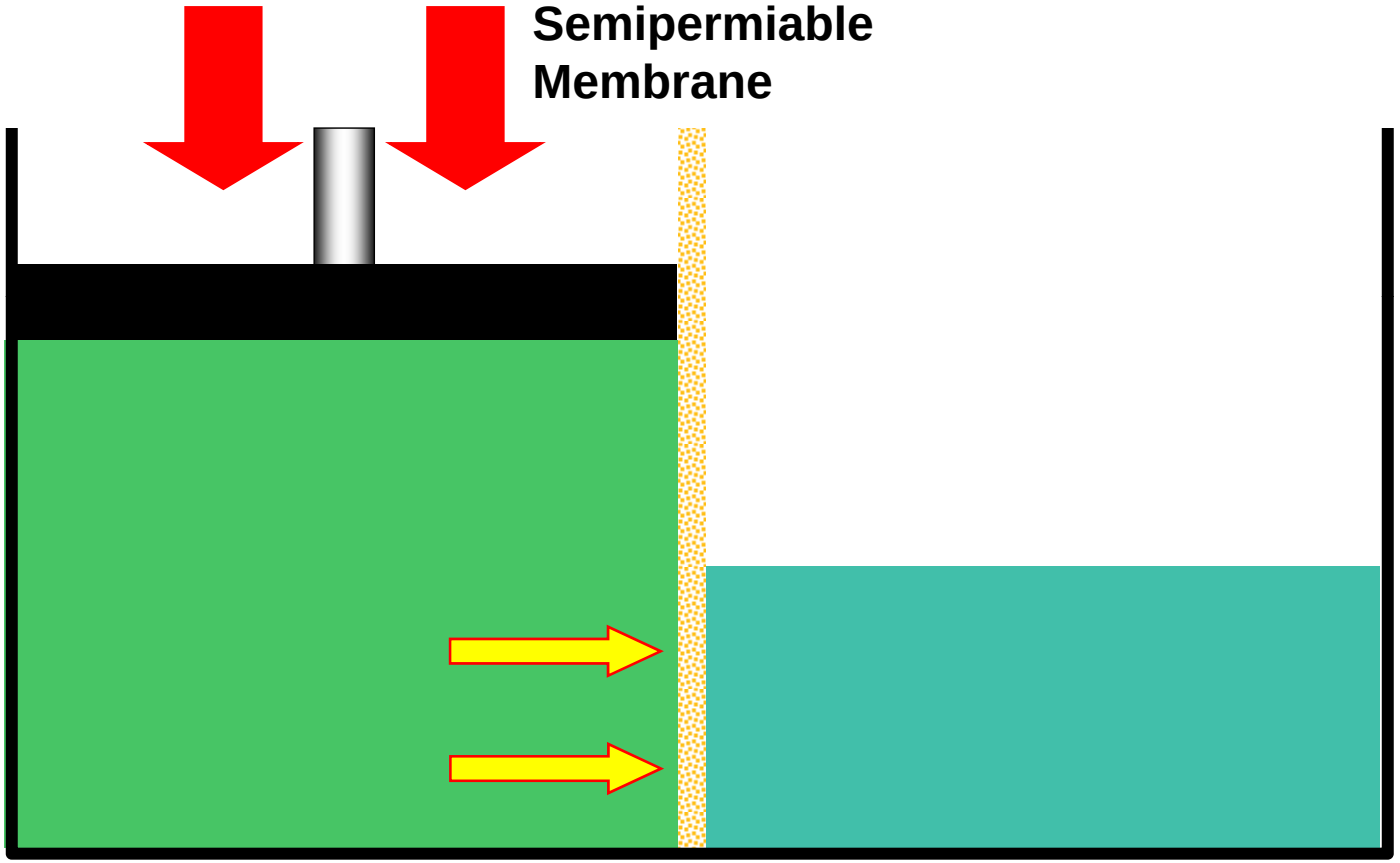
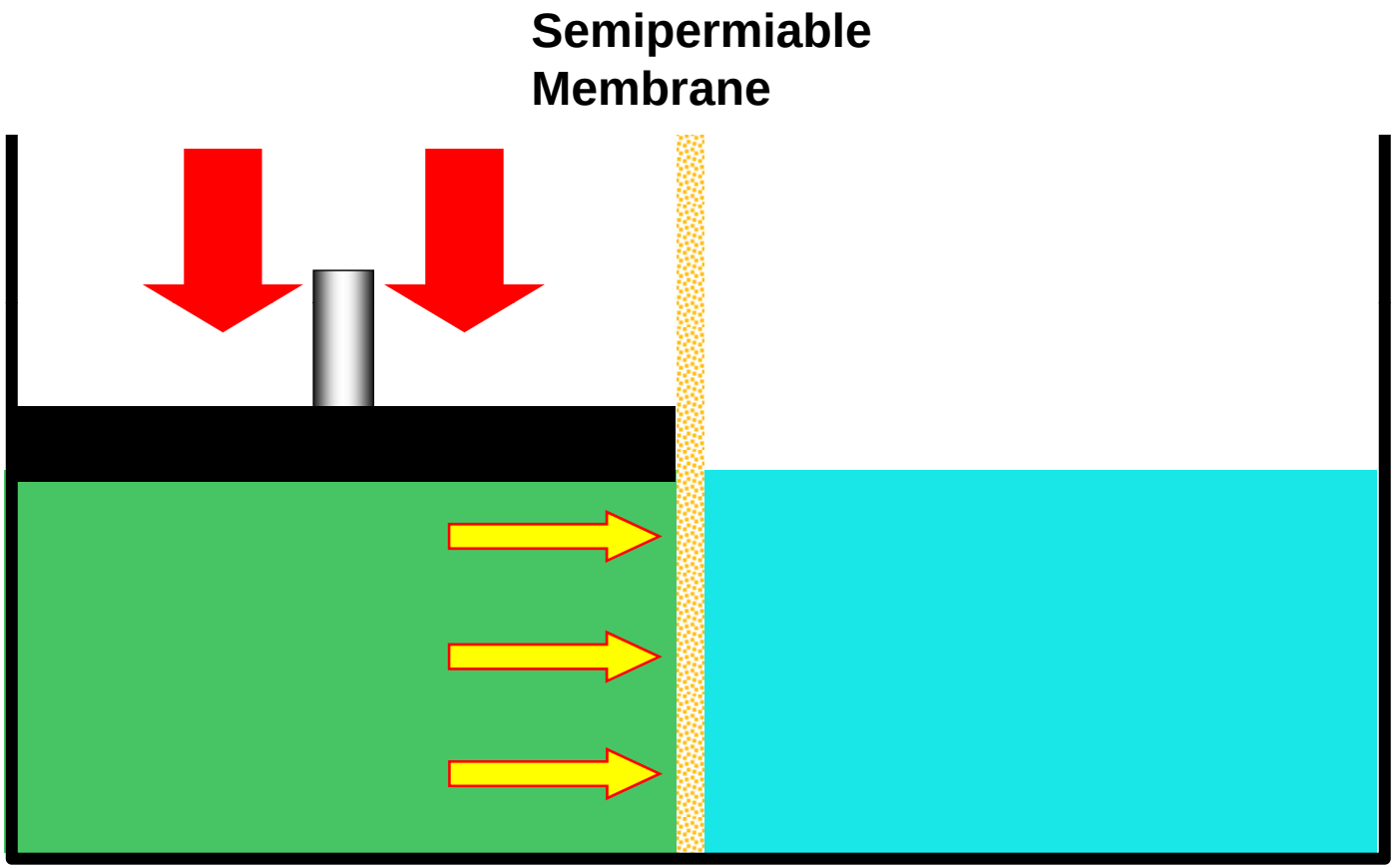
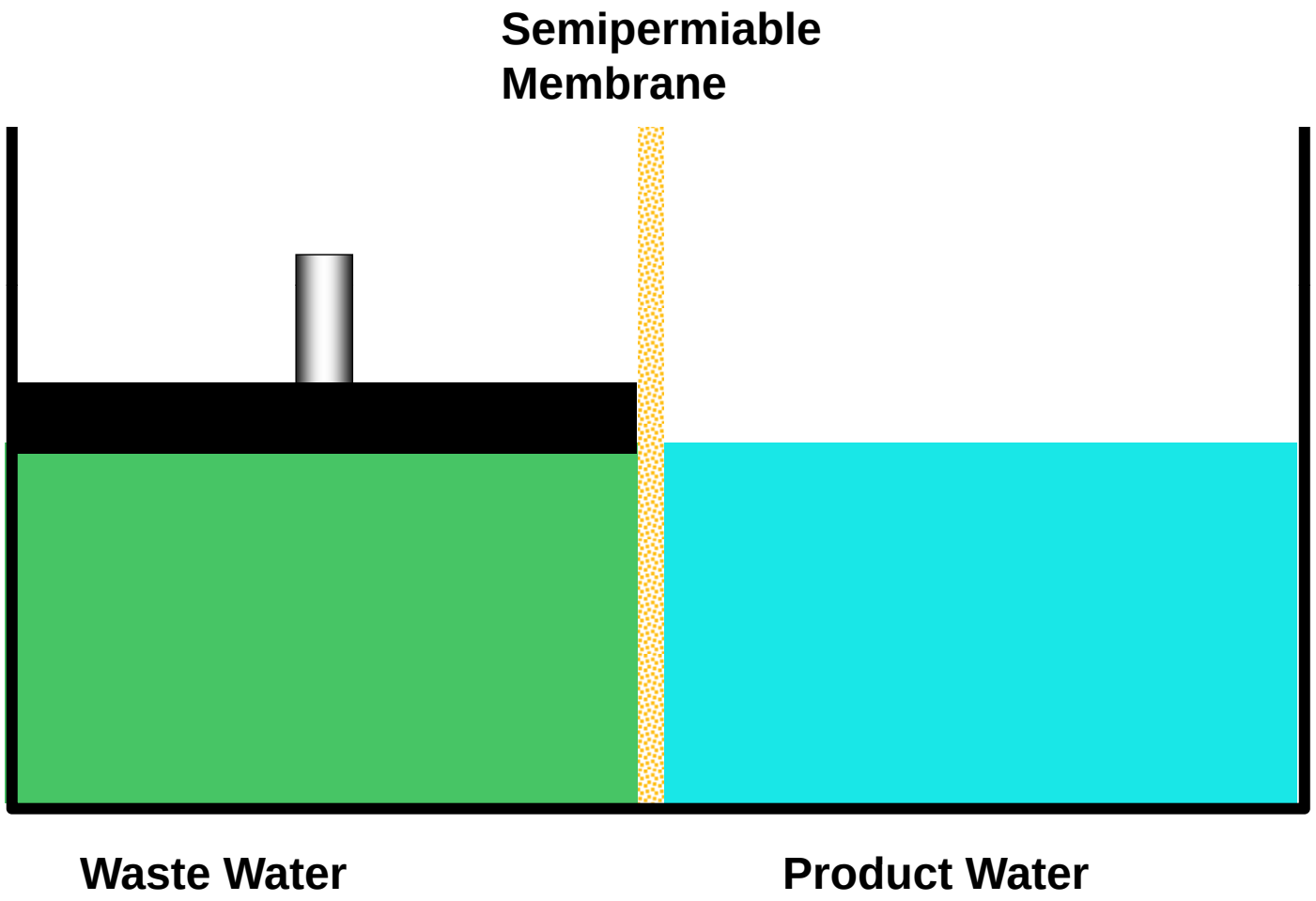


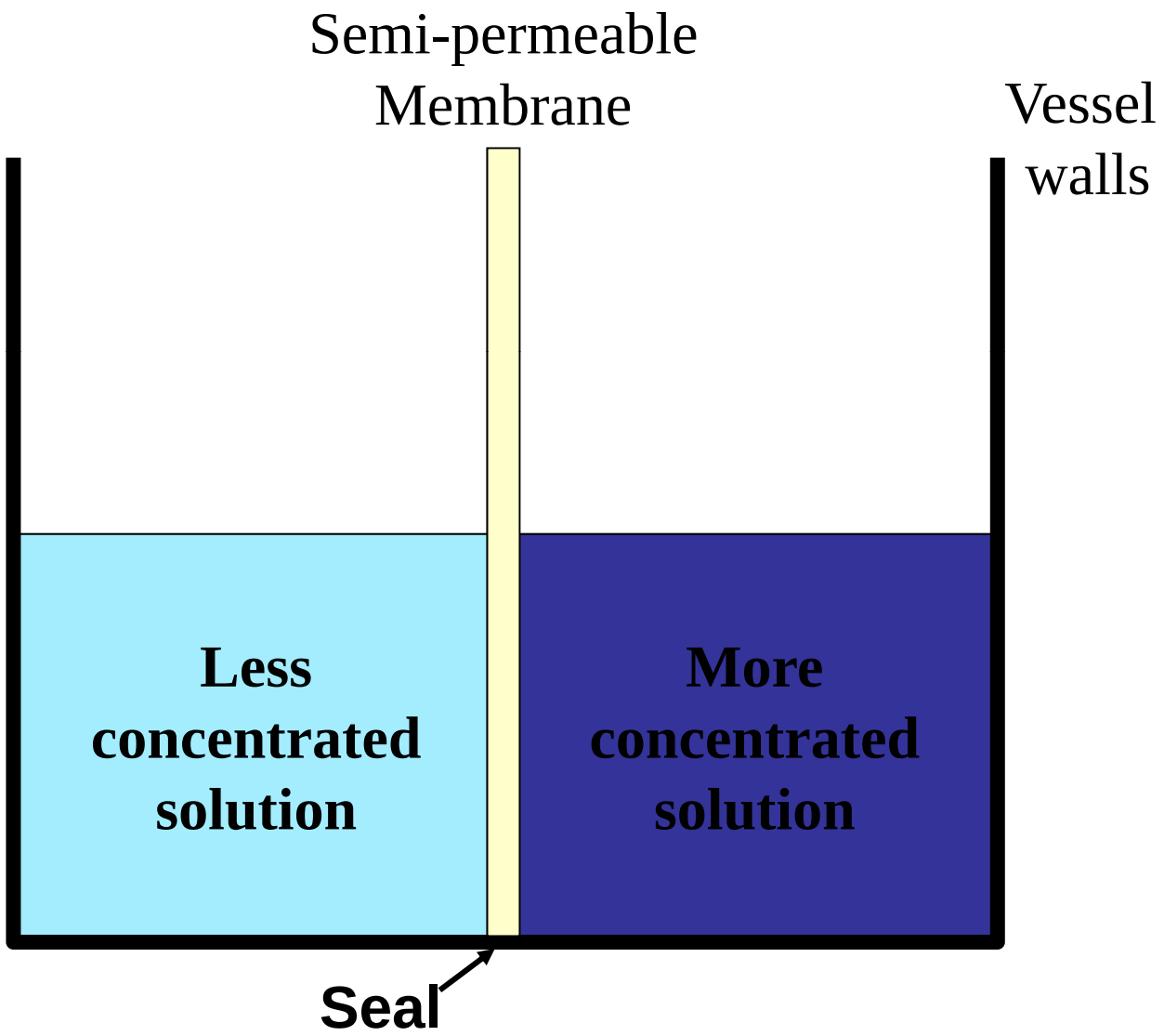
Reverse Osmosis



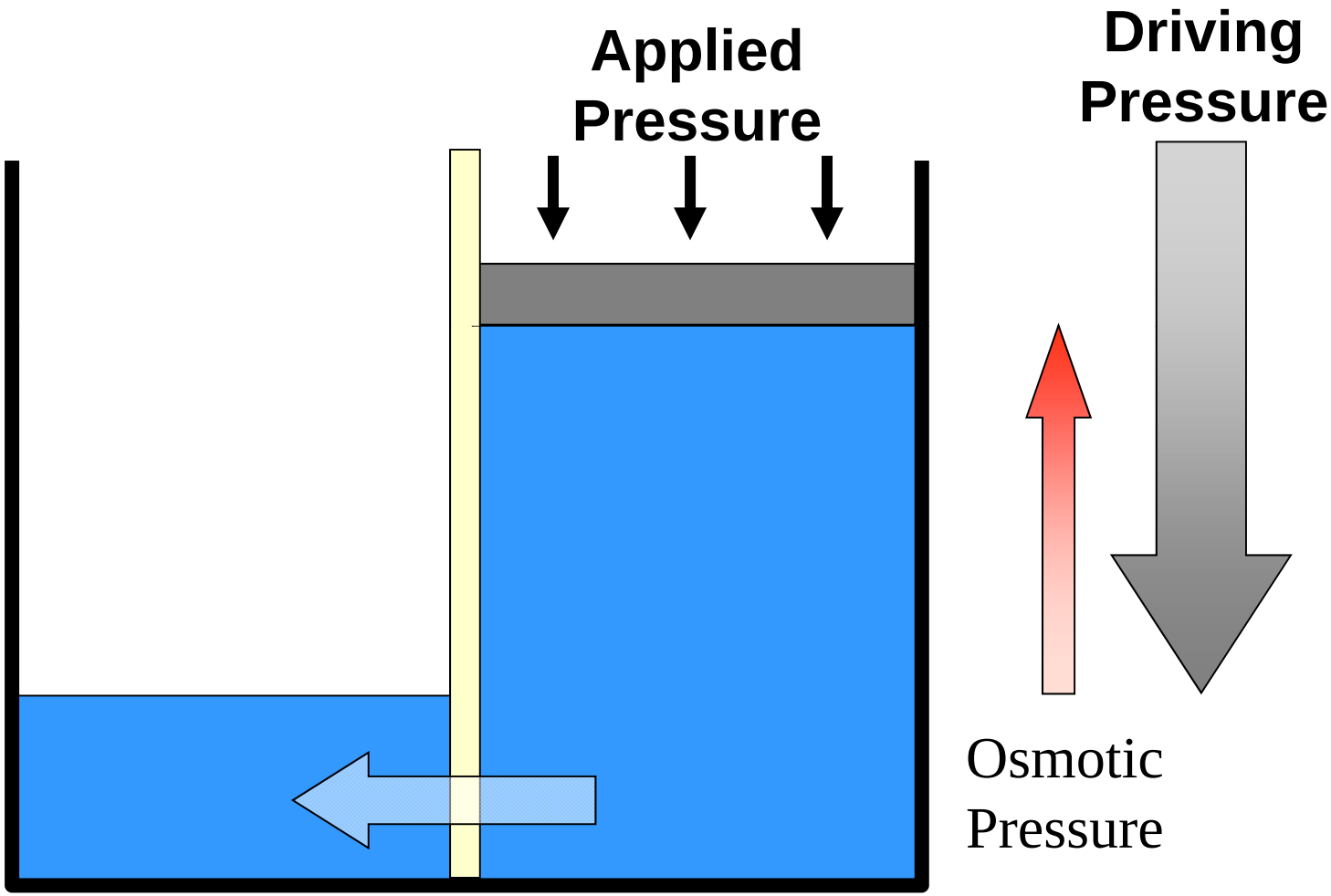
Reverse Osmosis



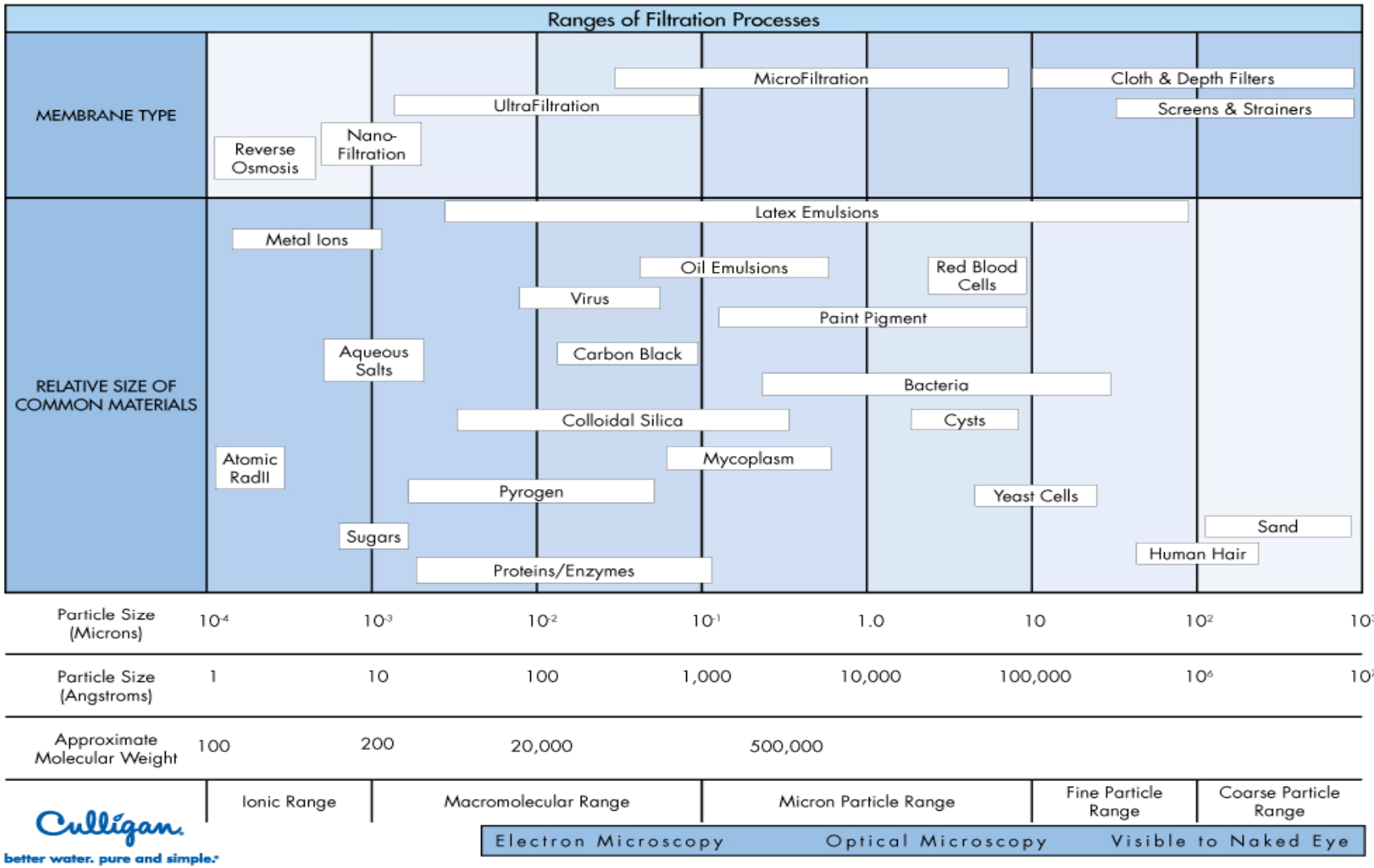
An Osmotic Cell



Reverse Osmosis



FILTRATION SPECTRUM

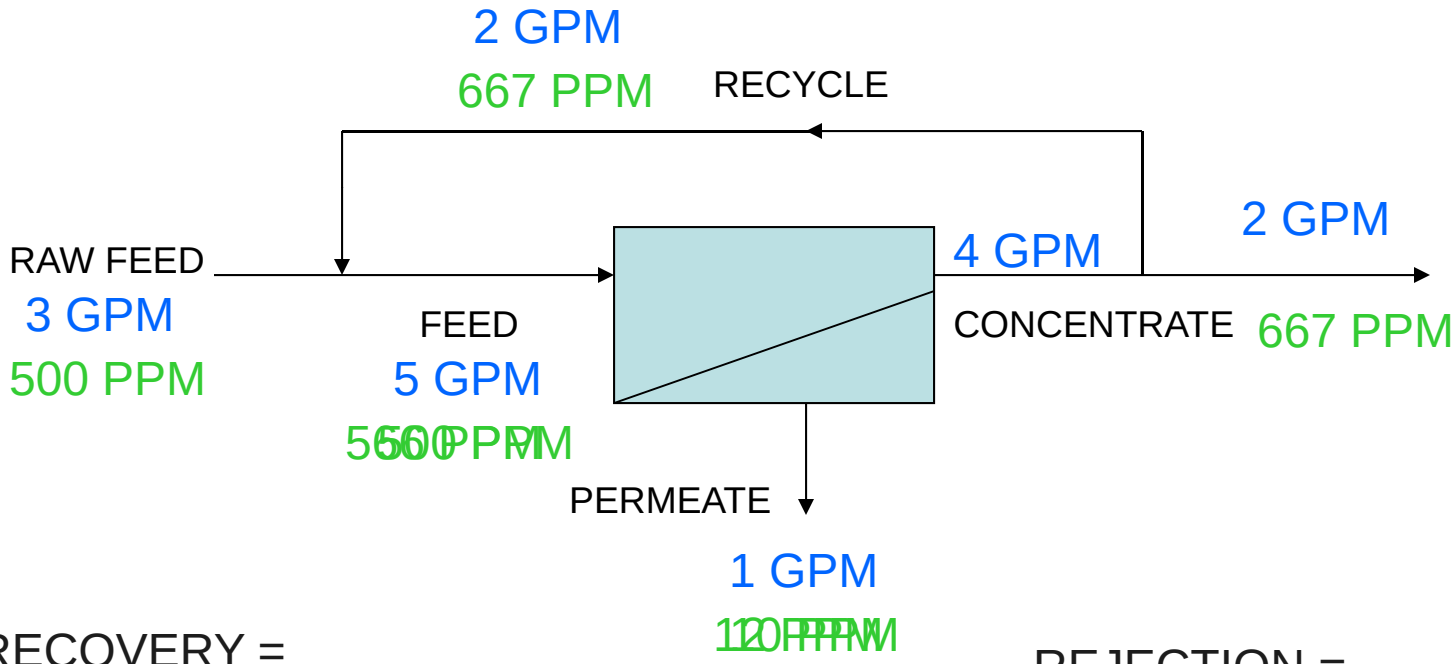


Culligan
better water. pure and simple.®

General RO System Design

FOR EXAMPLE, A SINGLE 4” MEMBRANE SYSTEM

BY ADDING RECYCLE, THE RECOVERY WILL INCREASE BUT PRODUCT TDS WILL ALSO GO UP



RECOVERY =

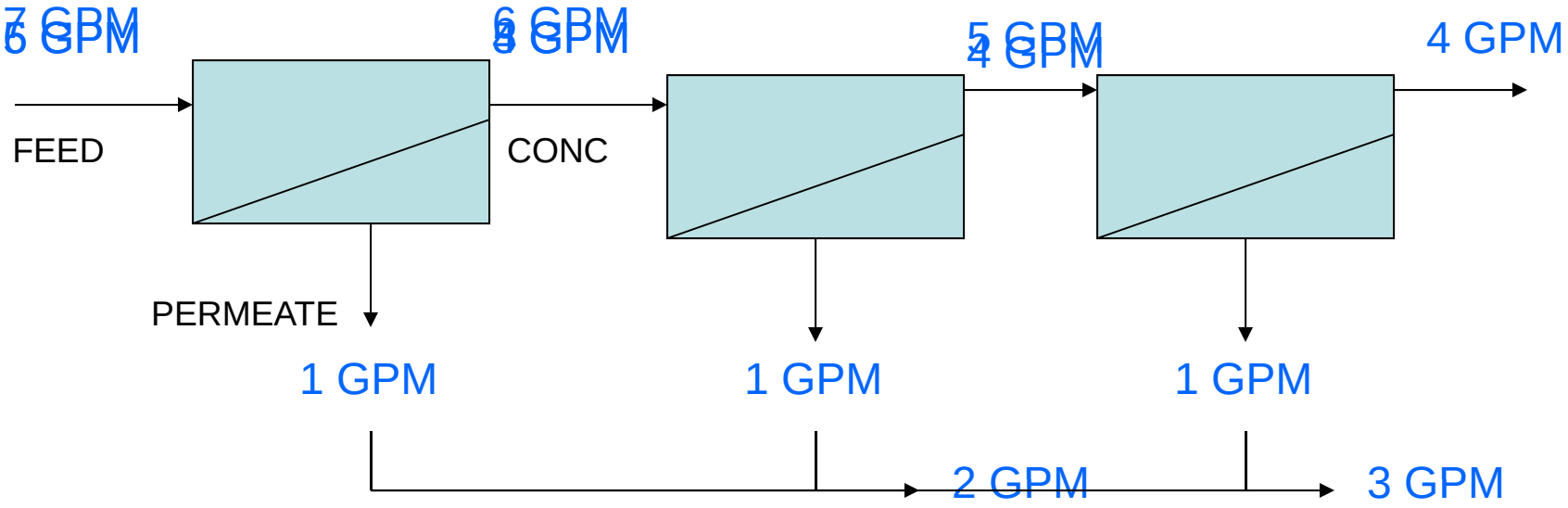
$$\frac{\text{PERM FLOW}}{\text{FEED FLOW}} \times 100 =$$

REJECTION =

$$\left(1 - \frac{\text{PERM TDS}}{\text{FEED TDS}}\right) \times 100 = 98\%$$

General RO System Design

ADDING MORE MEMBRANES IN SERIES WILL ALSO INCREASE RECOVERY



RECOVERY =

PERM FLOW / FEED FLOW x 100 =

RO Selection and System Design

Brackish Water	4” Elements	8” Elements
Average Permeate Flow	1 GPM	5 GPM
Maximum Feed Flow	16 GPM	64 GPM
Minimum Concentrate Flow	4 GPM	20 GPM

Pretreatment

Water Problems	Feed Water Requirements	Media Treatment	Chemical Treatment
Suspend Solids (TSS)	NTU < 1 or SDI < 3 (5 max)	Depth Filter	Inject Coagulants/ Flocculants
Chlorine (Oxidizers)	0 ppm	Carbon Filter	Sodium Meta Bisulfite (SBS) (inject 2 x Cl conc.)
Hardness	Softened Water	Softener	Antiscalant (~ 5 ppm)
Bacteria	0 counts	Ultra Violet Light or Ozone	Chlorine

Pretreatment

Other Problematic Minerals

Water Problems	Feed Water Requirements	Media Treatment	Chemical Treatment
Iron, Hydrogen Sulfide	Fe (2+), 4 ppm Fe (3+), 0.1 ppm	Manganese Green Sand	1) Chlorinate 2) Filter 3) Dechlorinate
Silica	Will precipitate at ~150 ppm	NA	1) Special Antiscalant Dispersant. 2) Reduce RO Recovery

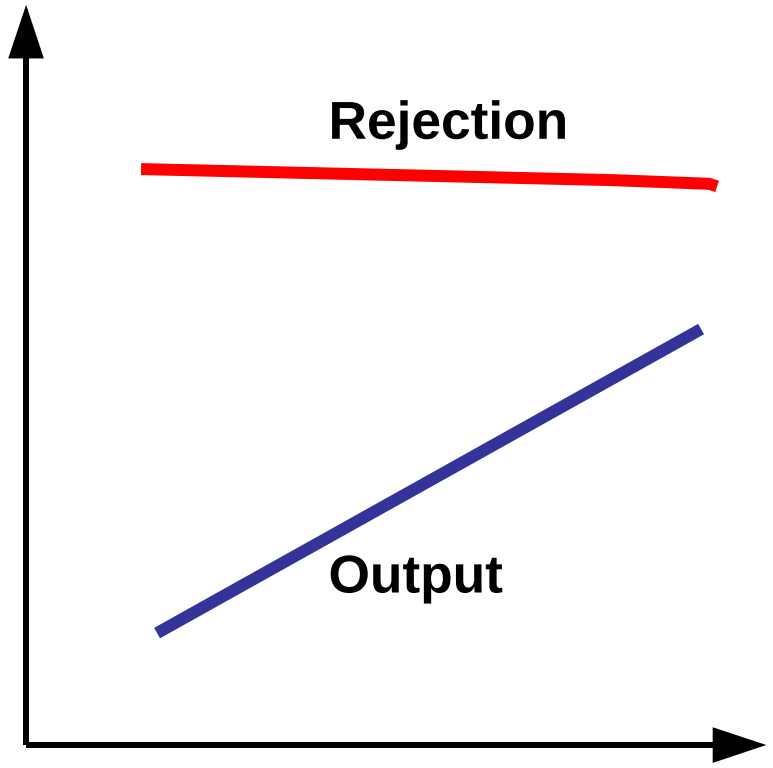
Factors to Consider When Sizing RO

- Temperature
- Pressure
- Total Dissolved Solids (TDS)

R.O. Performance Factors

Temperature

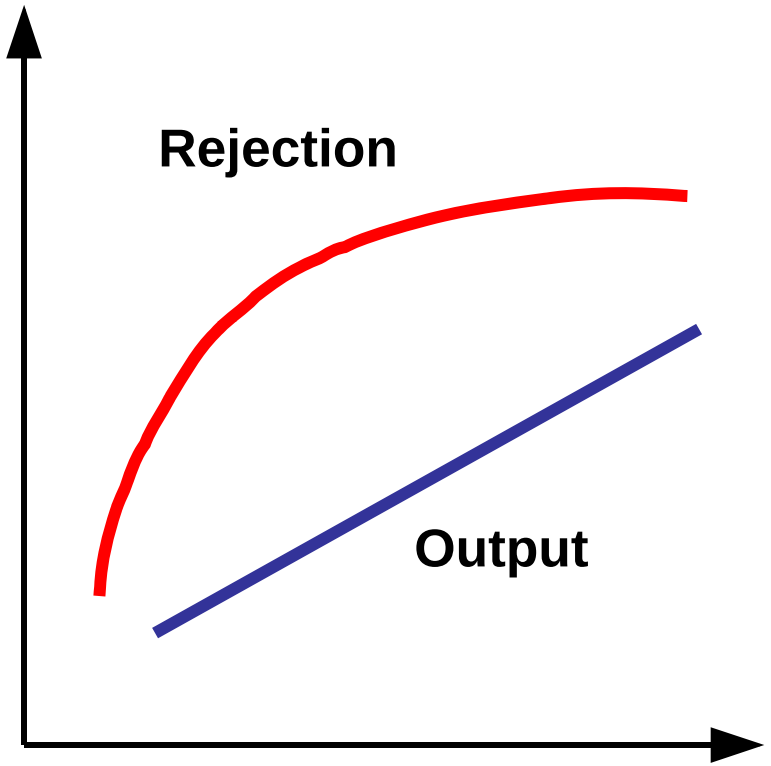
At lower temperatures, the water is denser, requiring more pressure to ‘push’ it through the membrane



R.O. Performance Factors

Pressure

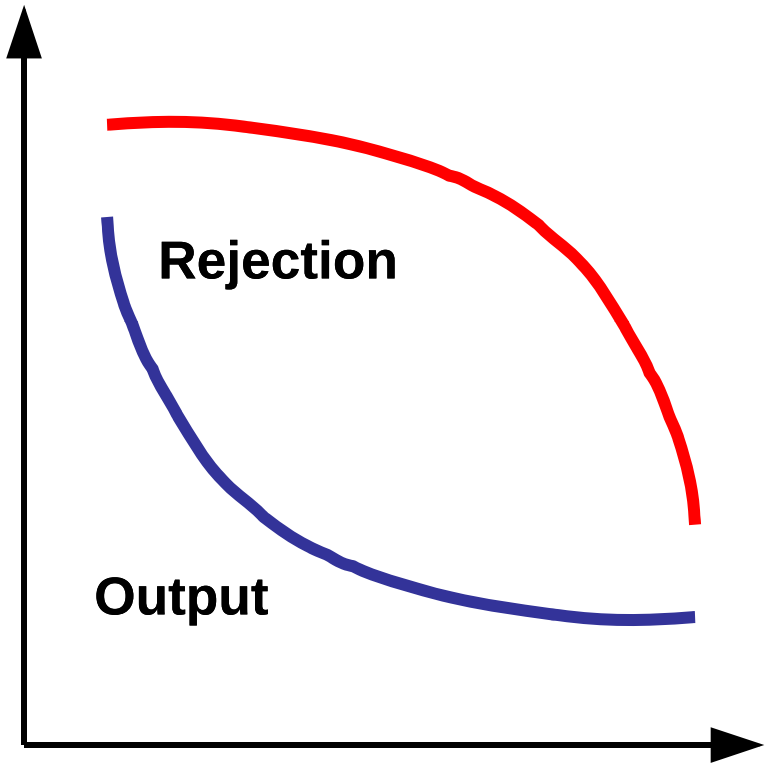
Higher pressure increases the quality and quantity of product water



R.O. Performance Factors

TDS

Higher TDS (total dissolved solids) raises the natural 'osmotic' pressure, which increases the water's tendency to reverse it's flow across the membrane



Benefits of Using RO

- Energy Savings-Reference DOE Report
- Water Savings via increased Boiler cycles of concentration COC (typically increase from 10 to 50 COC.
- Chemical Savings in the 25 to 50% range.
- Water reclamation via RO for reject water.

Case Study By Department of Energy

PETROLEUM

BestPractices
Technical Case Study

August 2001

OFFICE OF INDUSTRIAL TECHNOLOGIES
ENERGY EFFICIENCY AND RENEWABLE ENERGY, U.S. DEPARTMENT OF ENERGY

BENEFITS

- Lower energy costs because of fewer boiler blowdowns
- Lower maintenance costs
- Lower waste disposal costs
- Total annual savings of $200,000

APPLICATIONS

Naturally occurring minerals can foul the tubes in steam boilers, resulting in reduced boiler efficiency and run length. Removal of these minerals is essential for efficient boiler operation. At the Flying J Petroleum Refinery, a new reverse osmosis unit has proven more reliable than the hot lime softener it replaced. This new process also requires less operator attention.

Installation of Reverse Osmosis Unit Reduces Refinery Energy Consumption

Summary

In August 1998, the Flying J Petroleum Refinery replaced its hot lime softener, which removes hardness and alkalinity from boiler feed water, with a reverse osmosis unit. The benefits of this replacement project include lower energy costs from reduced boiler blowdown requirements, as well as lower maintenance costs from the elimination of handling lime slurry and its associated cleaning and plugging problems. Another benefit is lower waste disposal costs because no lime is discarded. The total savings are estimated to reach $200,000 annually.

Plant Overview

The Flying J Petroleum Refinery, located in Salt Lake City, Utah, processes 25,000 barrels per day (BPD) of crude oil. The new reverse osmosis unit provides make-up water to four natural-gas-fired package boilers and six waste-heat boilers.

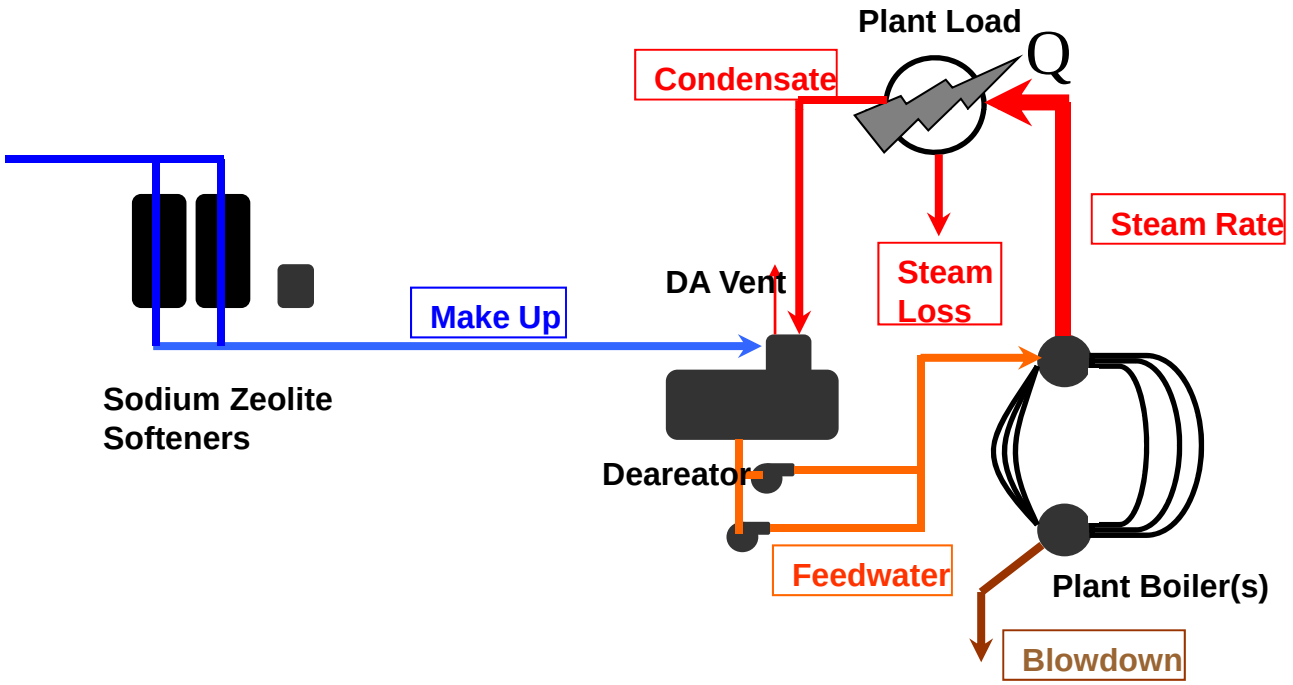
Project Overview

Naturally occurring minerals in the city water supply, such as calcium, magnesium, and silica, tend to precipitate out in the refinery's steam boilers, resulting in tube

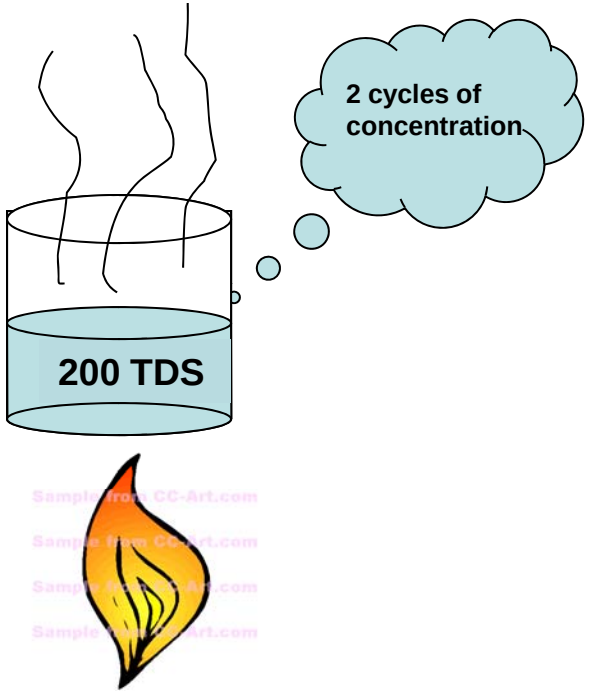
CLEANER WATER INCREASES EFFICIENCY OF FLYING J'S BOILERS

RO Boiler Savings

Typical Boiler PFD



Cycles of Concentration - COC



Calculating % Blowdown

$$\text{FW Cycles} = \frac{\text{Neutralized Boiler Conductivity}}{\text{Feedwater Conductivity}}$$

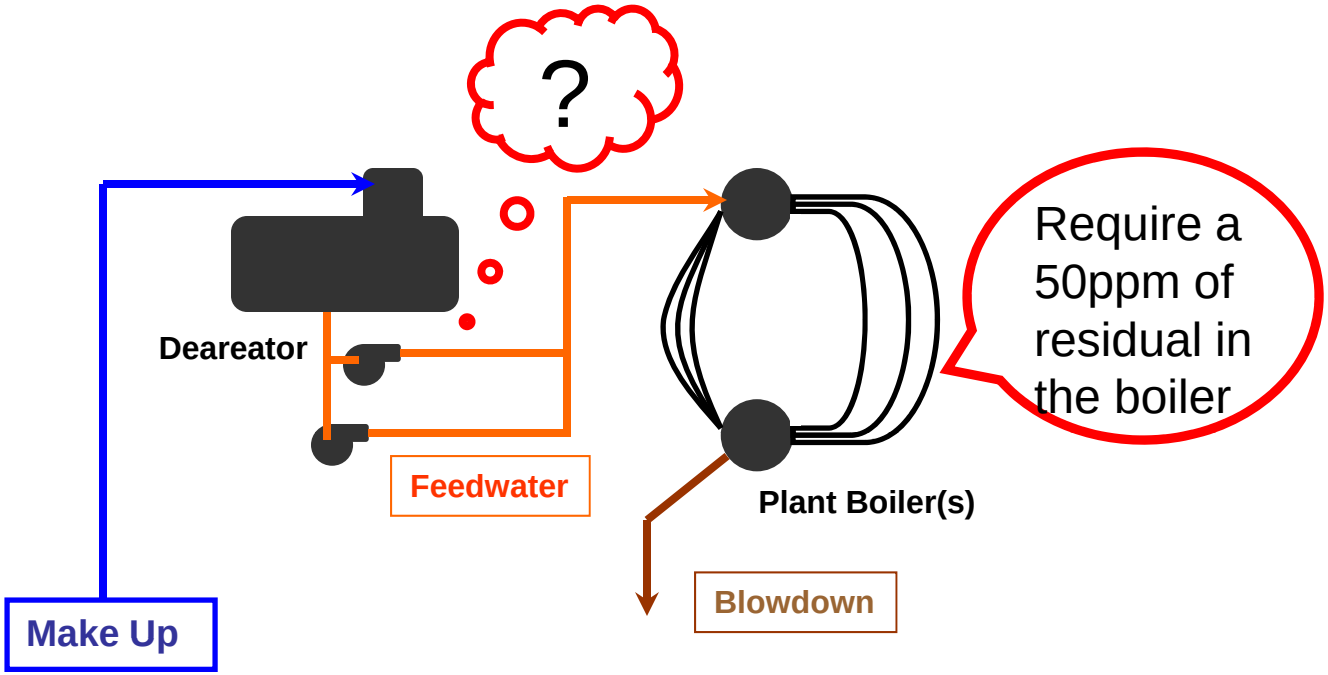
$$\text{\% Blowdown} = \frac{1}{\text{Feedwater Cycles}} \text{ X100}$$

Dearator/ Feedwater mmhos = 100 ppm

Neutralized Boiler mmhos = 3000 ppm

= 3.33 % Blowdown

Effects of Concentration on Chemical Feed Rate



Boiler Residual / FW Cycles = Feed Rate

Feed rate at 10% blowdown or 10 FW cycle = 5 ppm

Feed rate at 2% blowdown or 50 FW cycles = 1 ppm

Boiler ASME Limits

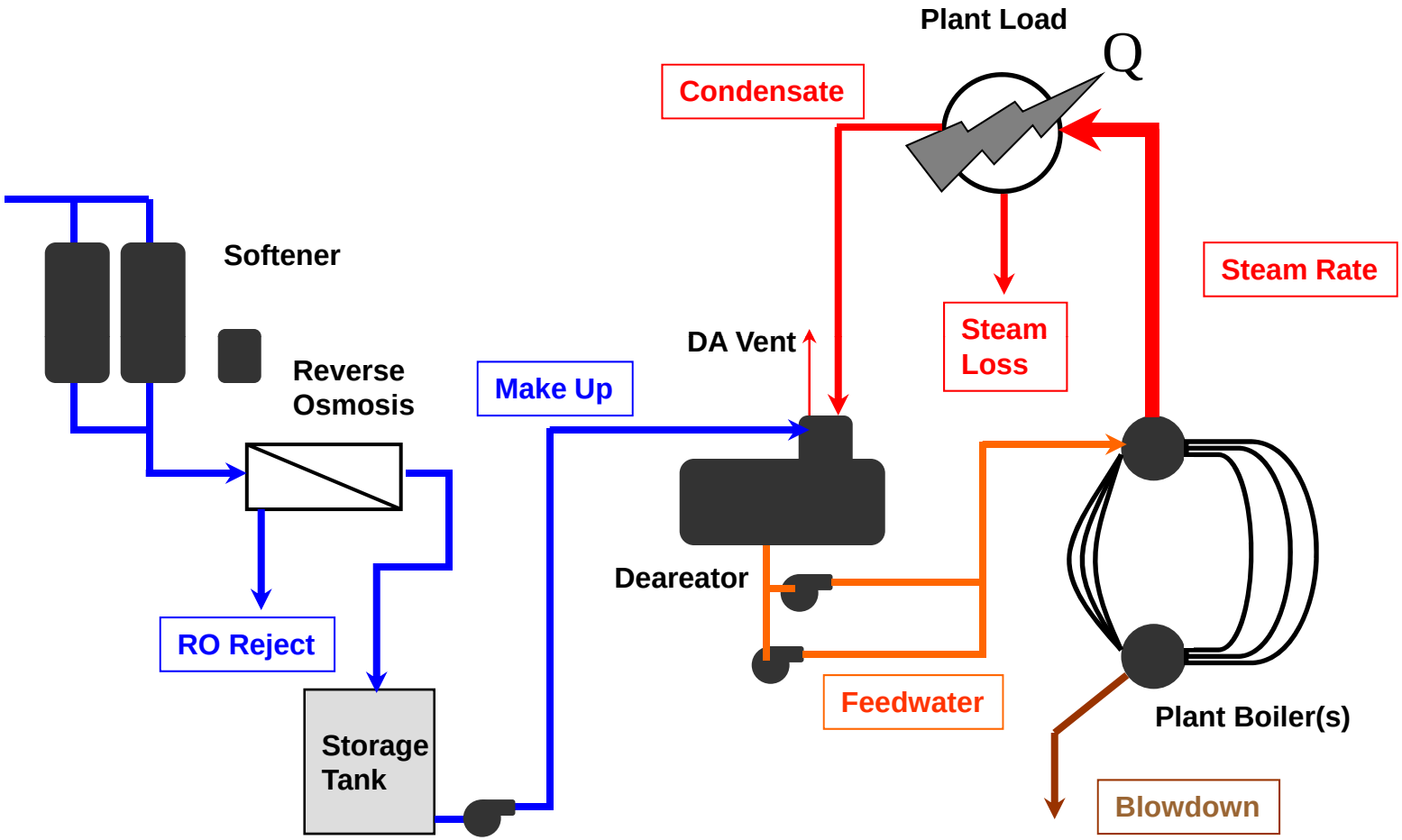
Boiler PSIG	0-300	301-450	451-600	601 -750
TDS max (ppm)	700-3500	600-3000	500-2500	200-1000
ALK. max (ppm)	350	300	250	200
TSS Max (ppm)	15	10	8	3
Conductivity (µmho/cm)	1100-5400	900-4600	800-3800	300-1500
Silica max (ppm SiO2)	150	90	40	30

Typical Water Analysis

	Municipal	Softened	RO
Calcium	78	0.5	0.00
Magnesium	33	0.3	0.00
Sodium	50	160.2	1.77
Potassium	3.8	3.8	0.05
Strontium	0.2	0.2	0.00
Chloride	43.6	45	0.47
Sulfate	13.5	13.5	0.09
Bicarbonate	106	106	1.34
Flouride	0.5	0.5	0.00
Silica	22.4	22.4	0.29
pH	8	8	6.10
mmhos	311	320	6.50

in PPM as CaCO3

RO added to Process Flow Diagram



Other Benefits

- Possible improved steam quality
  - Lower operating boiler alkalinity
  - Lower operating boiler TDS
- Reduction in Neutralizing Amine feed rate
  - Easier Compliance with FDA steam requirements
  - Better Condensate corrosion protection
- Softened RO reject water could be put to use.
  - Once thru cooling
  - Wash down water, truck rinsing
  - Possible CIP rinses
  - Other non critical apps.

Potential Objections

- RO water is corrosive won't it hurt my boiler ?
- The RO water is too pure and is not good for boiler chemistry ?
- RO's are not reliable.
- There is a lot a water loss with an RO.
- My water treater said I should use a Dealkalizer

Case Study: Pet Food Manufacturer

All steam directly injected into finished product

- 0% Condensate Return
- 270 BHP Average Production
- 10.7% Blowdown
- $1.00/ Therm , $0.04 / KWH
- Savings Energy $25,746/ year
- Savings Chemicals $12,500/ year

  Total $38,246/ year

- RO System Capital Costs: $38,000/ year

Minimum Conditions for Justifications

- **350 BHP or 12,000 lbs/hr**
- **50% Condensate Return or Less**
- **Gas Prices $1.00 per Therm**
- **Feed water TDS 350**
- **% Blowdown >7.5% or 13 Feed water Cycles**

Energy Saving Calculator Boiler Energy Savings.xls

Georgia Pacific Case Study

CULLIGAN SUCCESS STORY

Georgia Pacific wanted to expand their water treatment and knew that a reverse osmosis system would bring them more in energy savings and chemical savings. With Culligan, their total annual savings is $52,711.00.

Customer: Georgia Pacific, Phillips, Wisconsin
Description of Business: Georgia Pacific is a leading manufacturer and marketer of building materials, including plywood, gypsum boards, lumber and engineered wood products. They have 300 locations in North America, South America and Europe. At this location, they manufacture interior hard board paneling and paint and finish it.
Contact: Frank Donovan, Maintenance Supervisor

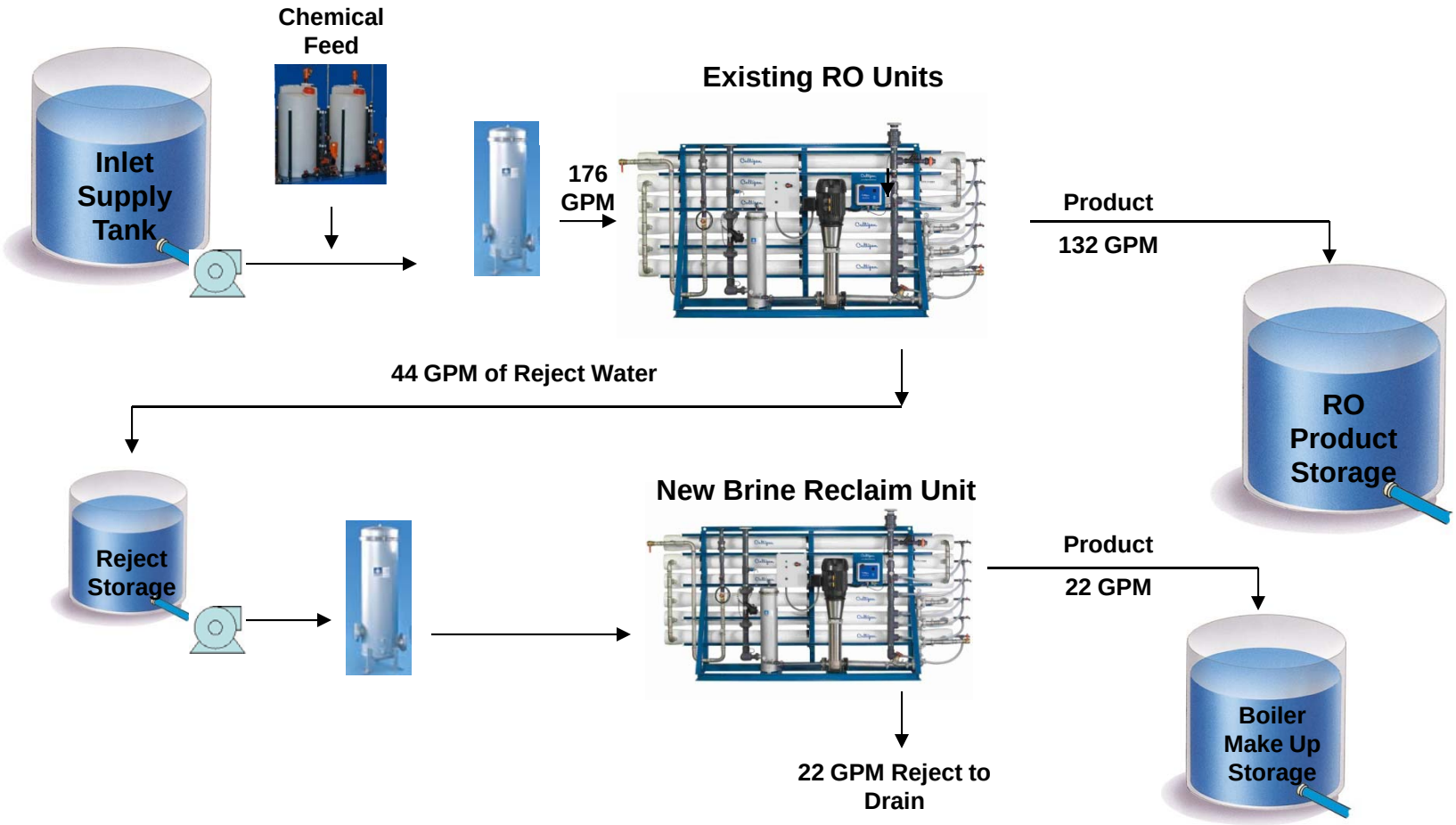
Situation/Problem:

- They have 2 boilers: primary boiler is a York-Shipley fire tube boiler rated at 24,000 pounds per hour; standby boiler is a Cleaver Brook water tube boiler rated at 20,000 pounds per hour.
- Their steam usage in the summer is 8,000 to 12,000 pounds per hour; winter usage is 14,000 to 20,000 pounds per hours. A significant amount of hot water is needed to produce the steam, resulting in high energy usage.
- After dissolved solids build up in a boiler, the equipment needs to "blow down" in order to send the impurities down the drain. Prior to the installation of equipment, they were blowing down approximately 4500 gallons of waste water per day.
- Feed water to boiler was 210 parts per million (TDS), or 12 grains per gallon on average. Heating water with a high level of TDS causes significant scale build-up. Heating elements in the boiler have to heat through the scale before reaching the water, thus causing high energy use. For boilers, it's best to have no more than 3-5 grains per gallon or ideally, less than one grain per gallon!

Culligan
better water. pure and simple.®

RO Brine Reclaim

PFD Brine Reclaim Example



<u>Saved 11,500,000 gallons /yr of city water</u>
Boiler Blowdown reduced from 25% to 2%
Netting: $61,000 per year in energy savings
50% Boiler Chemical savings

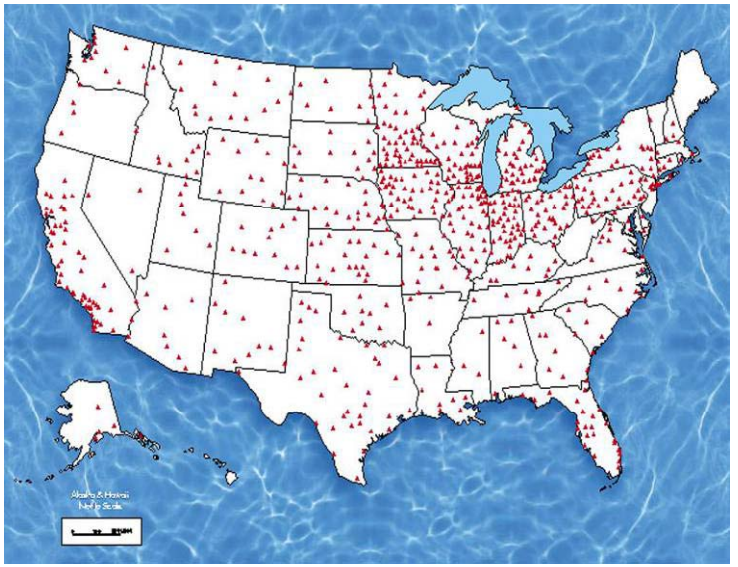
Culligan Background

- Culligan International
- Hall’s Water Group
- Culligan of Greater Cleveland

Culligan International Overview

US and Worldwide Support and Expertise

- Over 1400 dealerships around the world - local service and support
- Largest Pure Water play company
- Over 600 North American locations
- Service companies like Coca-cola, Toyota, John Deere, IBM and others
- 200 U.S. patents



Picture this from the 167th floor of the Burge Dubai…….where Culligan works..

Culligan's *Matrix Solutions* Concept

Modular Advanced Water Treatment Systems				
Pre-Treatment	Membrane Technology	Polish	Storage	Distribution
				
Control, Instrumentation, Pre-Packaging and Skid Mounting				

Culligan *Matrix Solutions* is based on building blocks

- Large array of applications covered with just a few components
- Simple, check the box system design concept
- Each piece pre-engineered to work interchangeably
- Pick the appropriate size, and all the pieces easily interconnect
- Great platform to implement our technology & third party's
- Maximizes potential to capture spend

Industrial Solutions: Capabilities and Resources

Process Development & Application

Resources (10)
- Application/Process Engineers (7)
- Chemist & Technicians (3)

Services
- Bench scale and onsite pilot testing programs
- Advanced Filtration: RO, microfiltration, ultrafiltration, nanofiltration

Tools
- Membrane / IX Resin Projection
- Proprietary Process Simulation software
- Reliability / Availability Modeling

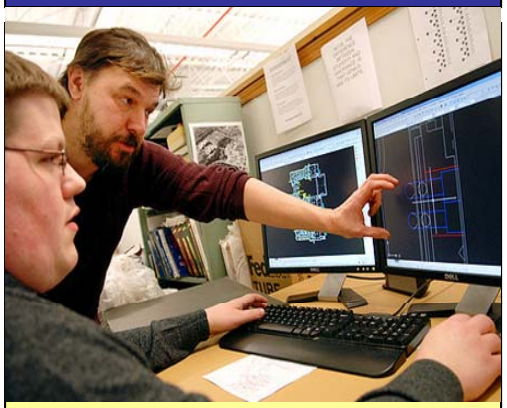
Project Management & Controls

Resources (10)
- Project Managers (6)
- Planner/Scheduler (1)
- Contracts Manager (1)

Skill Sets
- Senior Project Managers
- Proven record of leading large make-up water projects to successful conclusion

Tools
- Microsoft Project

Engineering, Design & Procurement



Resources (7)
- Engineering & Design Managers (2)
- Project Engineers / Mech Designers (2)
- Electrical & Automation Engineers / Designers (2)
- Procurement / Expediting (1)

Tools
- AutoCAD 2006, MicroStation v8
- PipeFlo (hydraulic calcs)
- Electronic Document Control (QAD, Arena)

Hall's Water Group Overview

- One of the Largest Culligan Dealers in the Franchise Network
- 29 locations from Coast-to-Coast
- Over 700 employees
- 6 locations in Ohio

Q & A

? ? ?