The Dow Chemical Company

About the Company

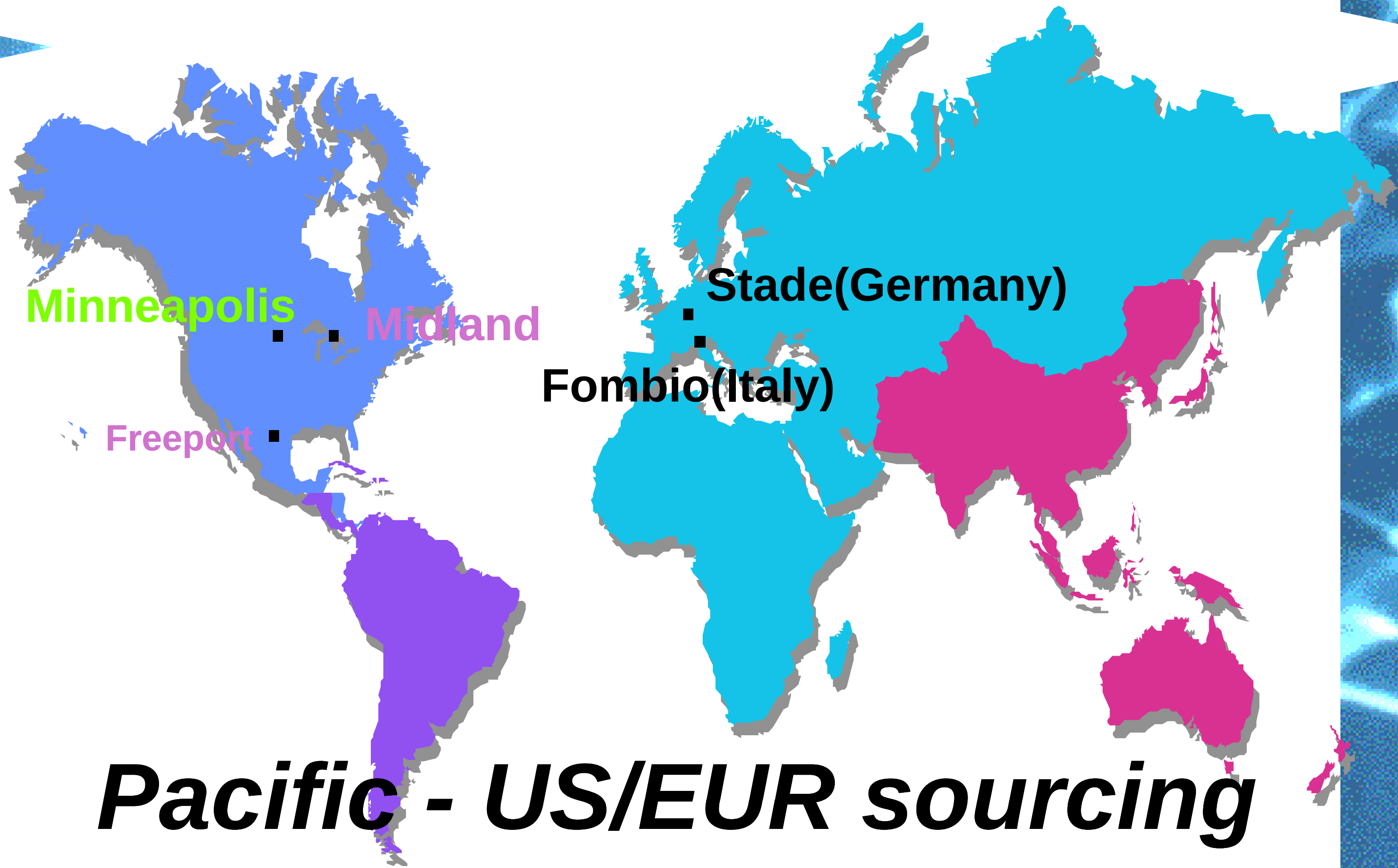
- Founded in 1897 by Herbert H. Dow in Midland, Michigan
- Fifth largest chemical company in the world, with sales of more than $20 billion
- 94 manufacturing sites in 30 countries
- More than 39,500 employees around the world

Liquid Separations

- ☞ **A global business within Specialty Chemicals**
- ☞ **Dowex* Ion Exchange Resins celebrated 60 years experience. They are the conerstone.**
- ☞ **FilmTec* Membranes are our fastest growing product line. Our 30th year in membranes**

THE DOW LIQUID SEPARATIONS

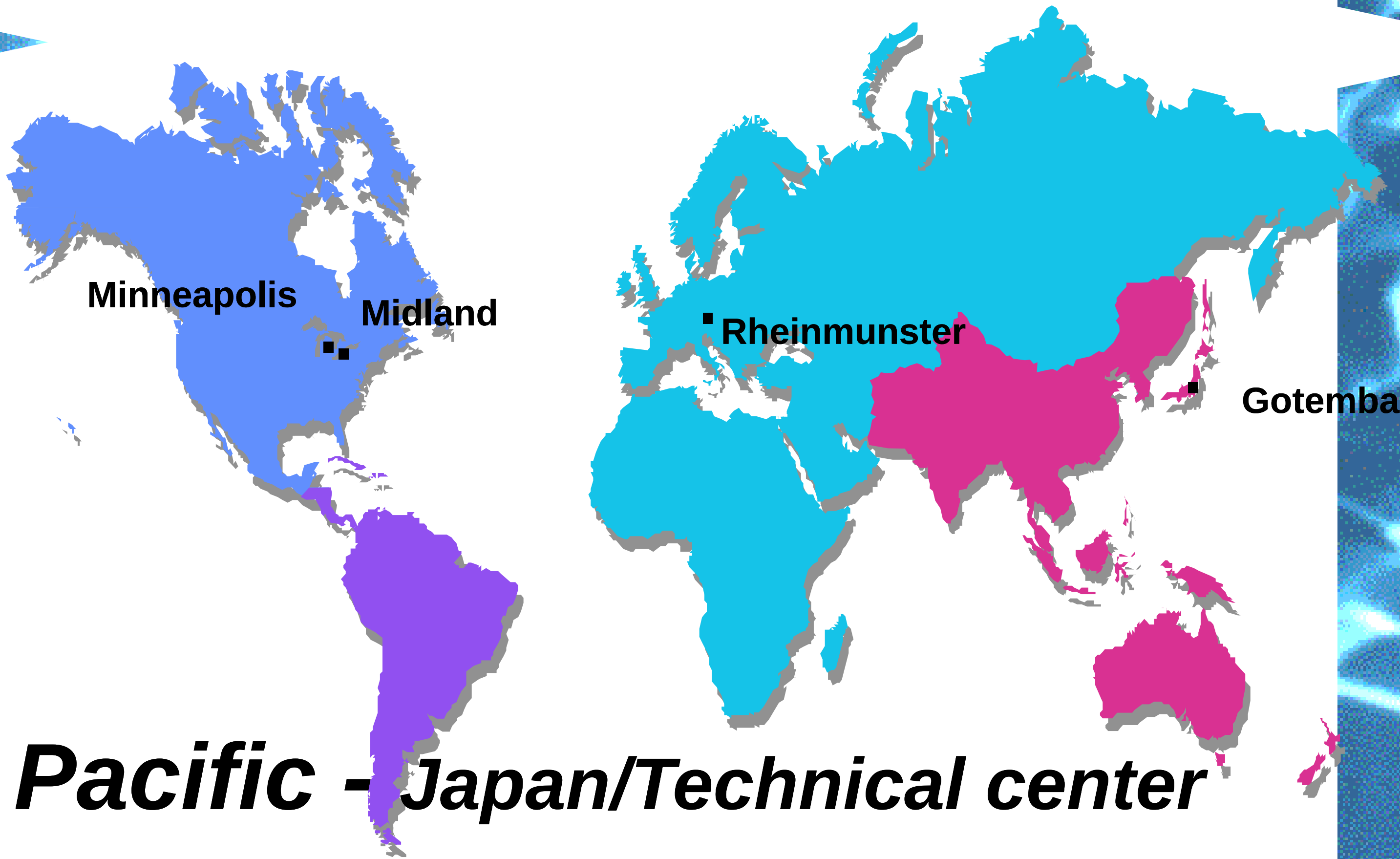
Manufacturing Sites



Pacific - US/EUR sourcing

THE DOW LIQUID SEPARATIONS

R&D, TS&D Locations



Pacific - Japan/Technical center

THE LIQUID SEPARATIONS

Products 1- IER

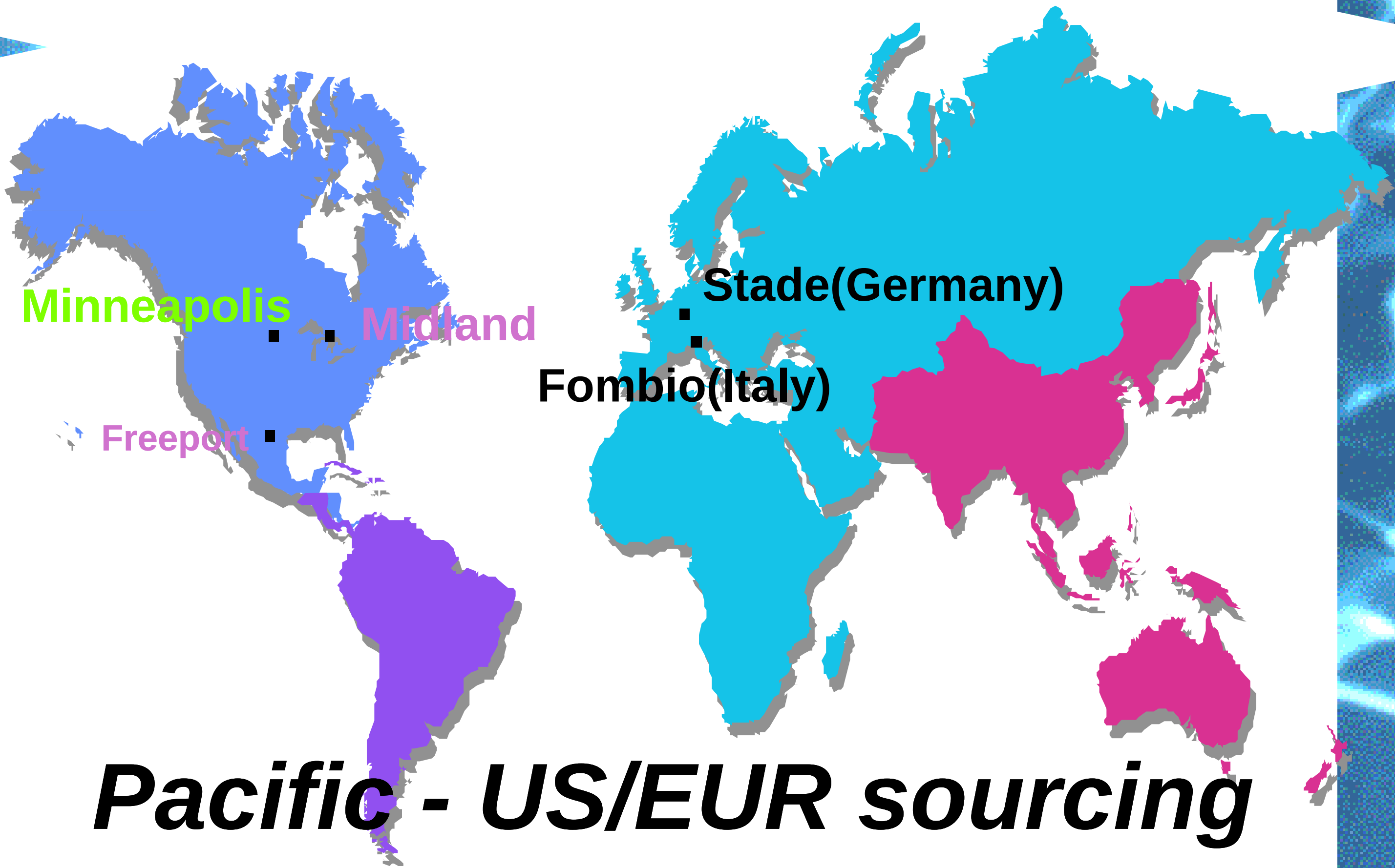
- Resin Materials
  - Ion Exchange Resins
    - Dowex(R) Gaussian Resins (HCR-S, SAR, SBR-P)
    - Dowex(R) UPS (Uniform) Resins
      - Marathon(R) Monospere(R)
  - Adsorbent Resins
    - Dowex(R) Optipore(R) Resins
- Technology License
  - UPCORE(R) Counter Current

THE LIQUID SEPARATIONS

Products -2 Membranes

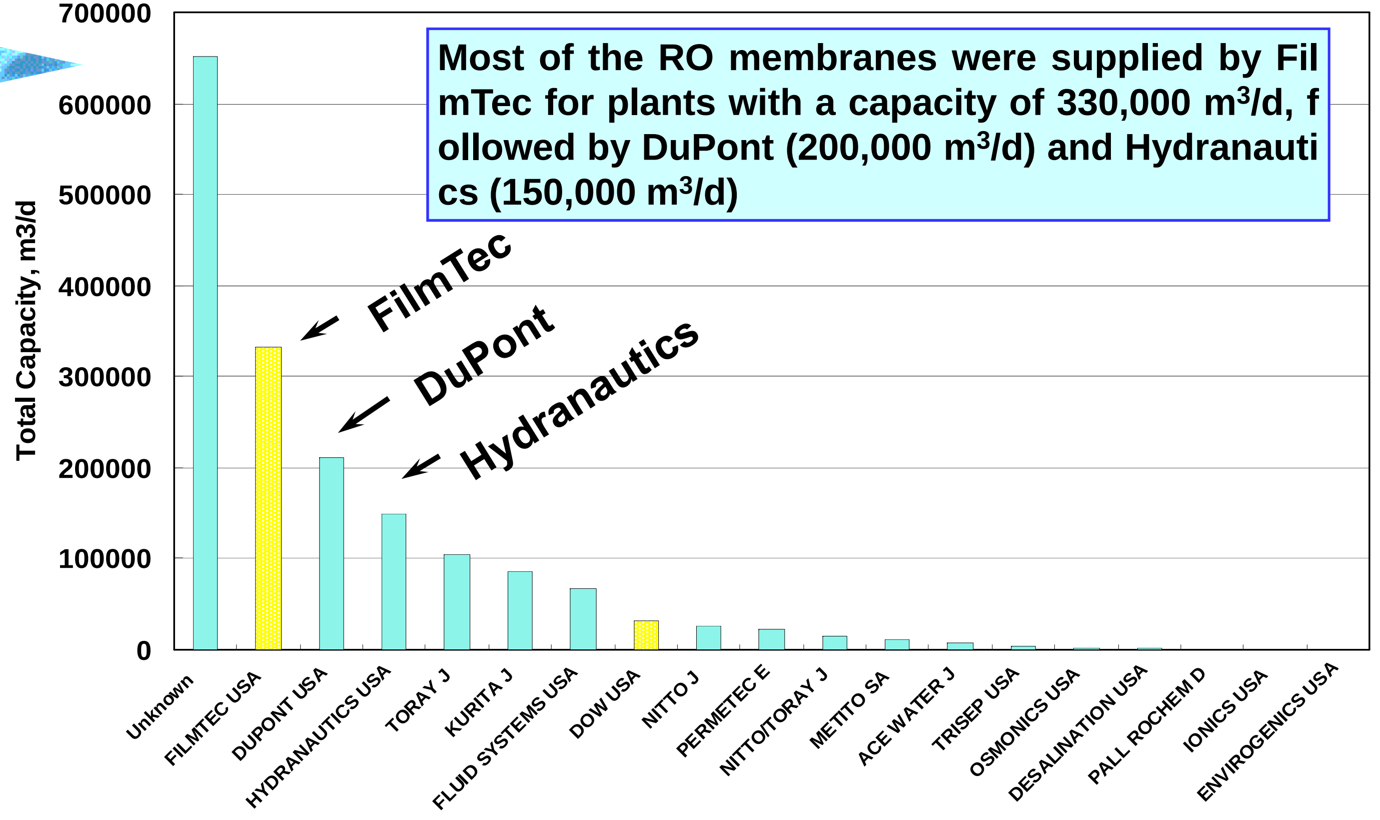
- Spiral Wound
  - RO
    - Filmtec$^{(R)}$ BW membrane (BW30-400, 365, 365FR..)
    - Filmtec$^{(R)}$ TW membrane
    - Filmtec$^{(R)}$ SW membrane
  - NF
    - Filmtec$^{(R)}$ NF membrane

THE DOW LIQUID SEPARATIONS
Manufacturing Sites



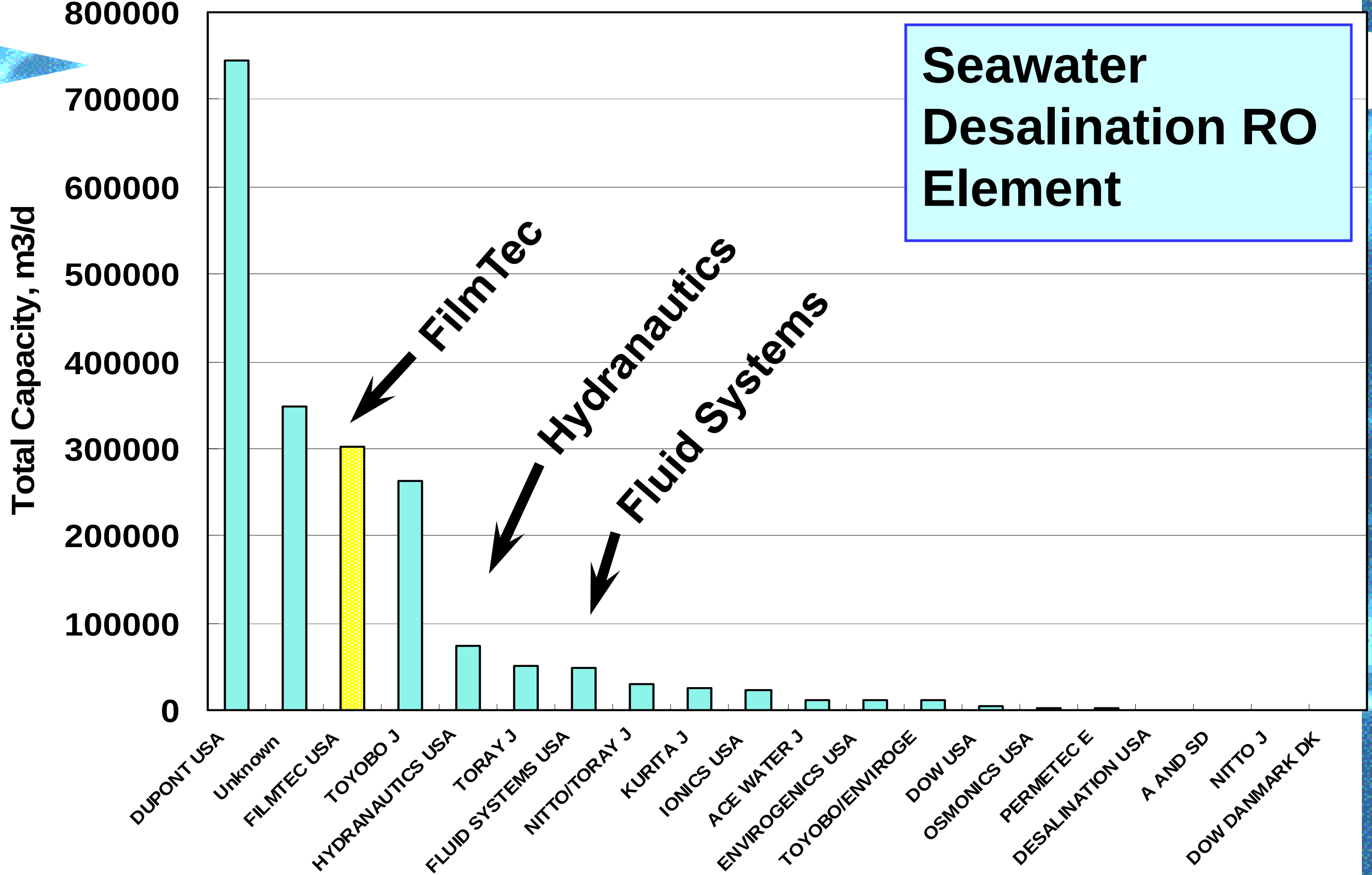
Pacific - US/EUR sourcing

CAPACITY of all land-based **RO** and **MS** desalting plants capable of producing 100 (100^3/d)/**UNIT** or more fresh water and contracted 1996 and 1997 vs. **MEMBRANE MANUFACTURER**



1998 IDA Worldwide Desalting Plants Inventory Report No.15

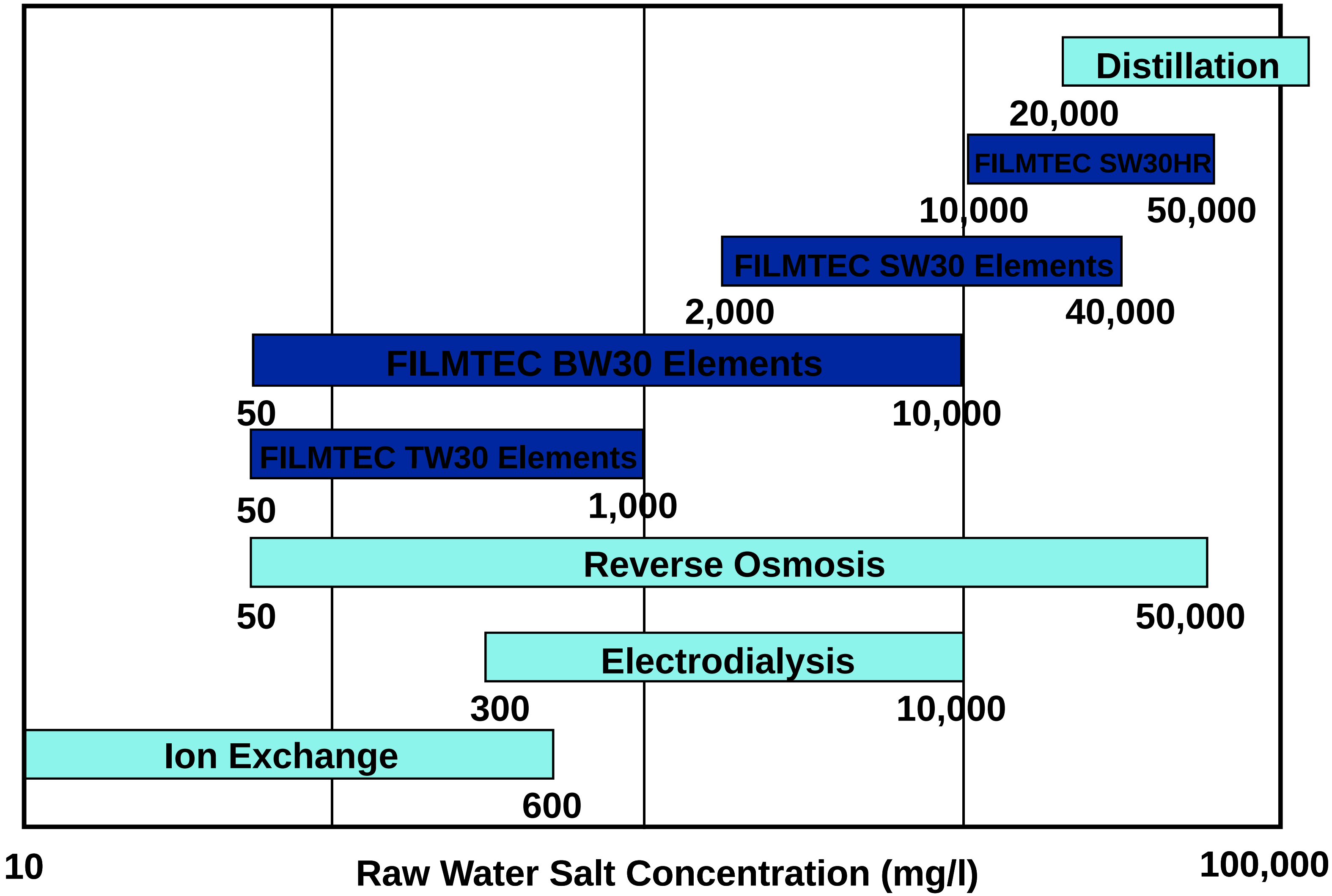
CAPACITY of all land-based **RO** and **MS** desalting plants using **SEAWATER** as **RAW WATER** and capable of producing 100 (100^3/d)/**UNIT** or more fresh water vs. MEMBRANE **MANUFACTURER**



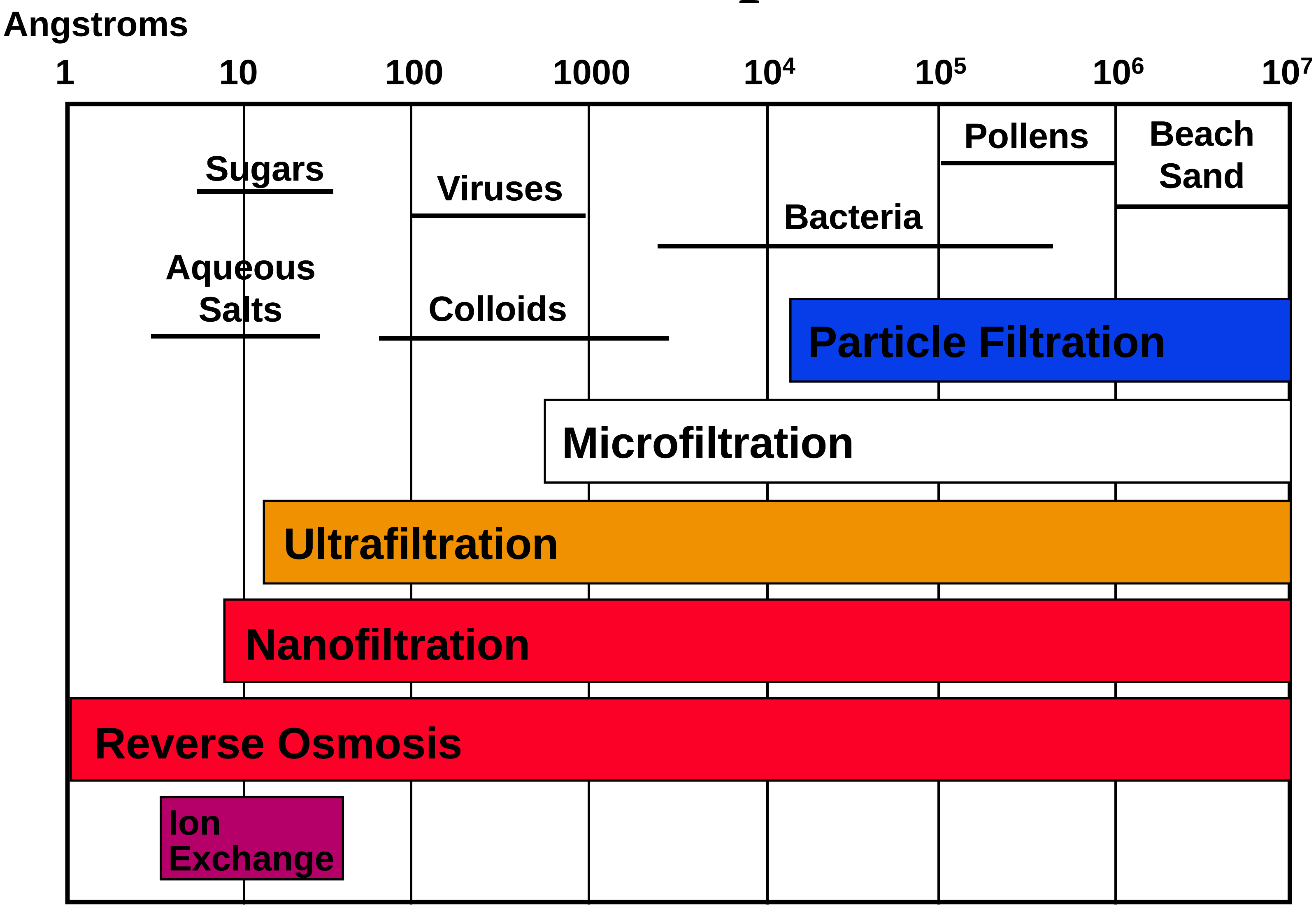
1998 IDA Worldwide Desalting Plants Inventory Report No.15

Fundamentals of Membranes and Reverse Osmosis

Major Desalination Processes



Filtration Spectrum



Microfiltration Involves

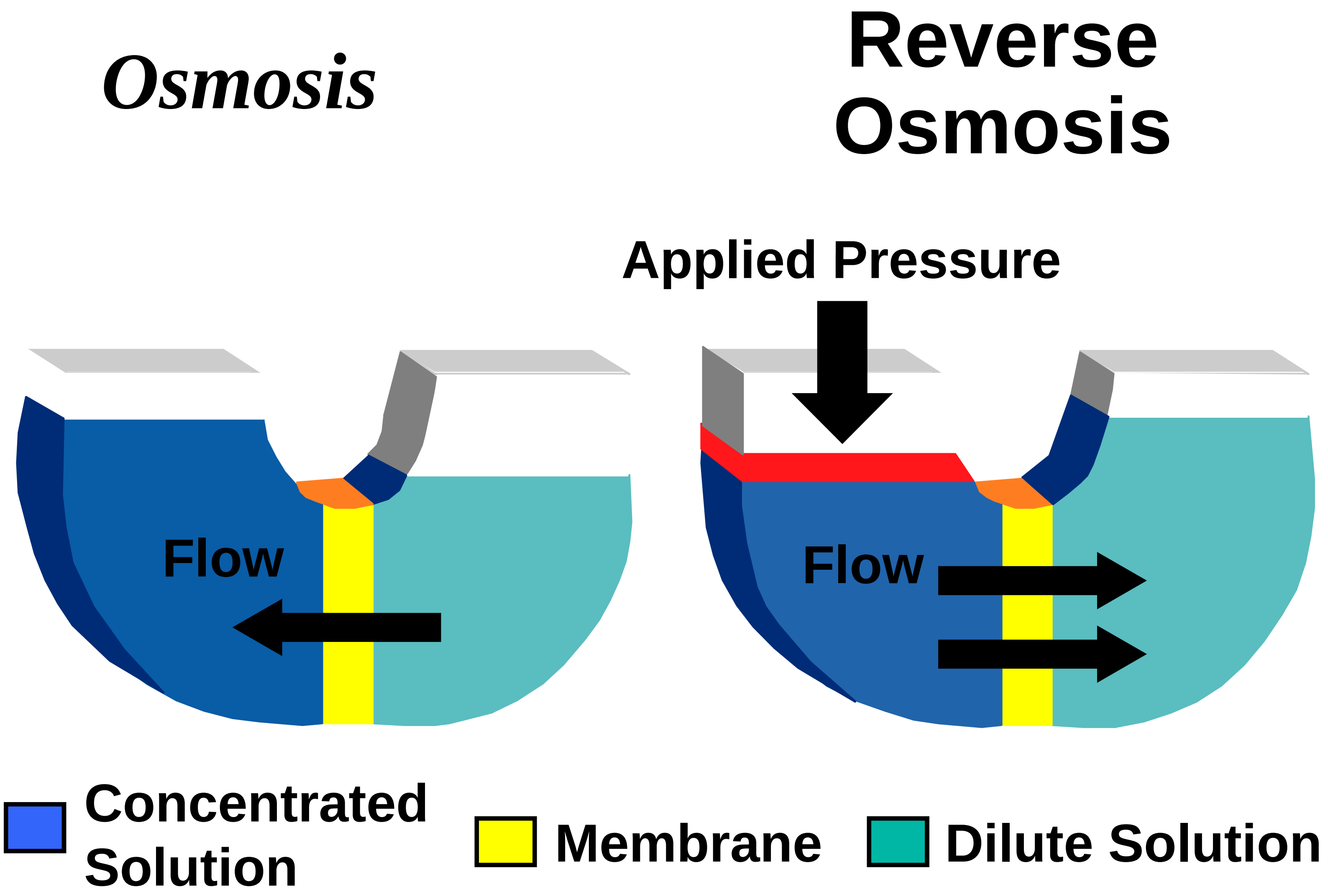
- ☞ **Separation mechanism based on pore size (≈ 0.1 to 1 micron)**
- ☞ **Pressure requirements independent of osmotic pressure of solution**
- ☞ **Usually "full-flow" rather than crossflow**

Ultrafiltration Involves

- ☞ **Separation mechanism based on pore size (up to 0.1 micron)**
- ☞ **Pressure requirement independent of osmotic pressure**
- ☞ **Crossflow filtration to provide sweeping flow at membrane surface**

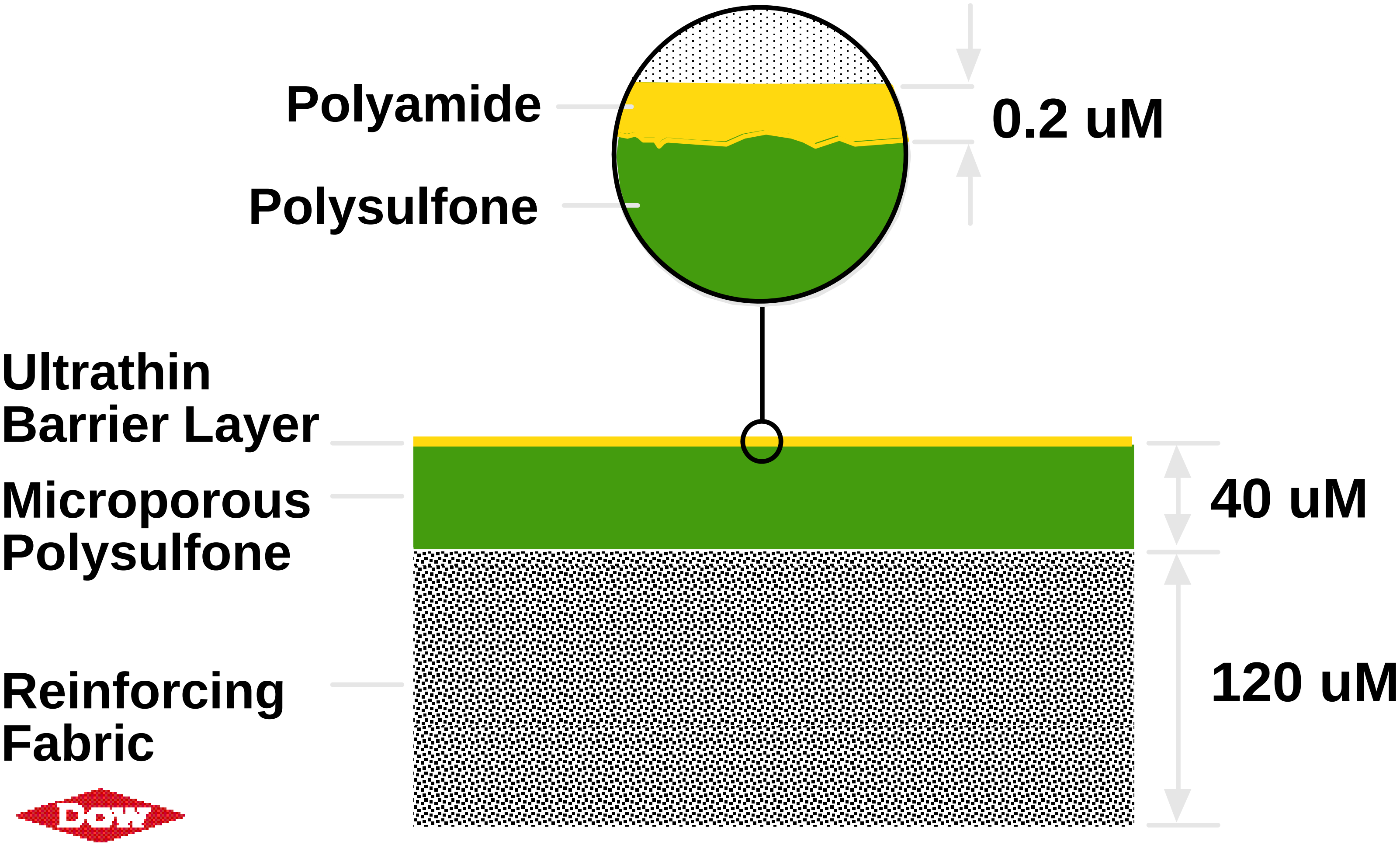
Nanofiltration Definition

- ☞ **Minimum size rejected on order of one nanometer**
- ☞ **Between RO and UF**
- ☞ **Operates at ultralow pressure**
- ☞ **Selective permeation of ionic salts and small solutes**

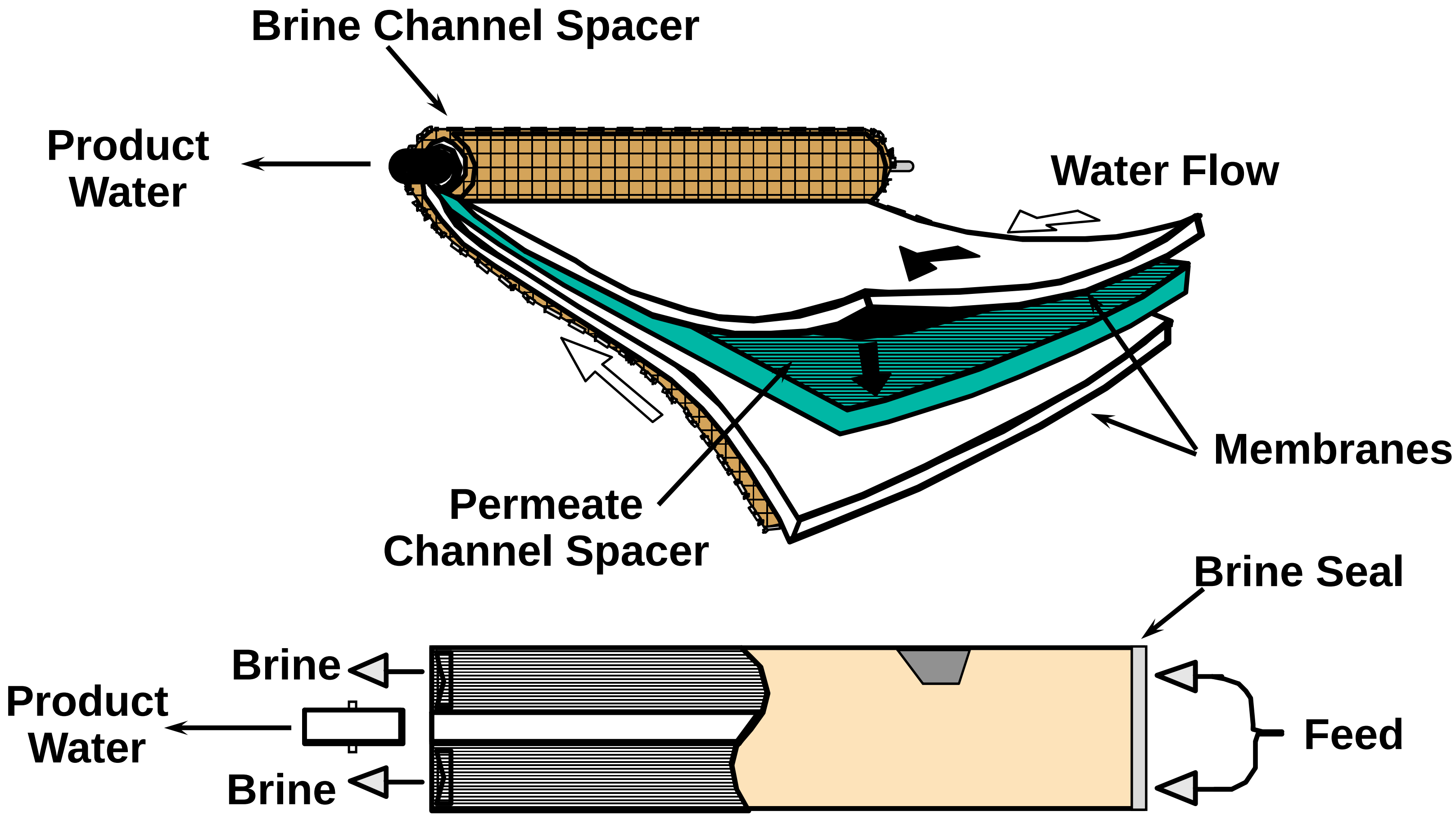


Osmosis
Reverse Osmosis
Applied Pressure
Flow
Flow
Concentrated Solution
Membrane
Dilute Solution

Schematic Cross-Section of Thin-film Composite Membranes



Spiral Wound Reverse Osmosis



Element Grade, Length, Diameter

Element Grade	Dia	Length
-TW30	≤2.5"	<40"
-BW30(HR,LE)	4.0"	40"
-SW30(HR)	8.0"	
-SG30		
-NF45(55,70,90),SR90		

Ex) BW30LE-440 (8040)

**(Brackish Water, Low Energy Membrane,
Diameter 8”, Length 40” (Surface Area 440 ft2)**

FT30 Reverse Osmosis Membrane

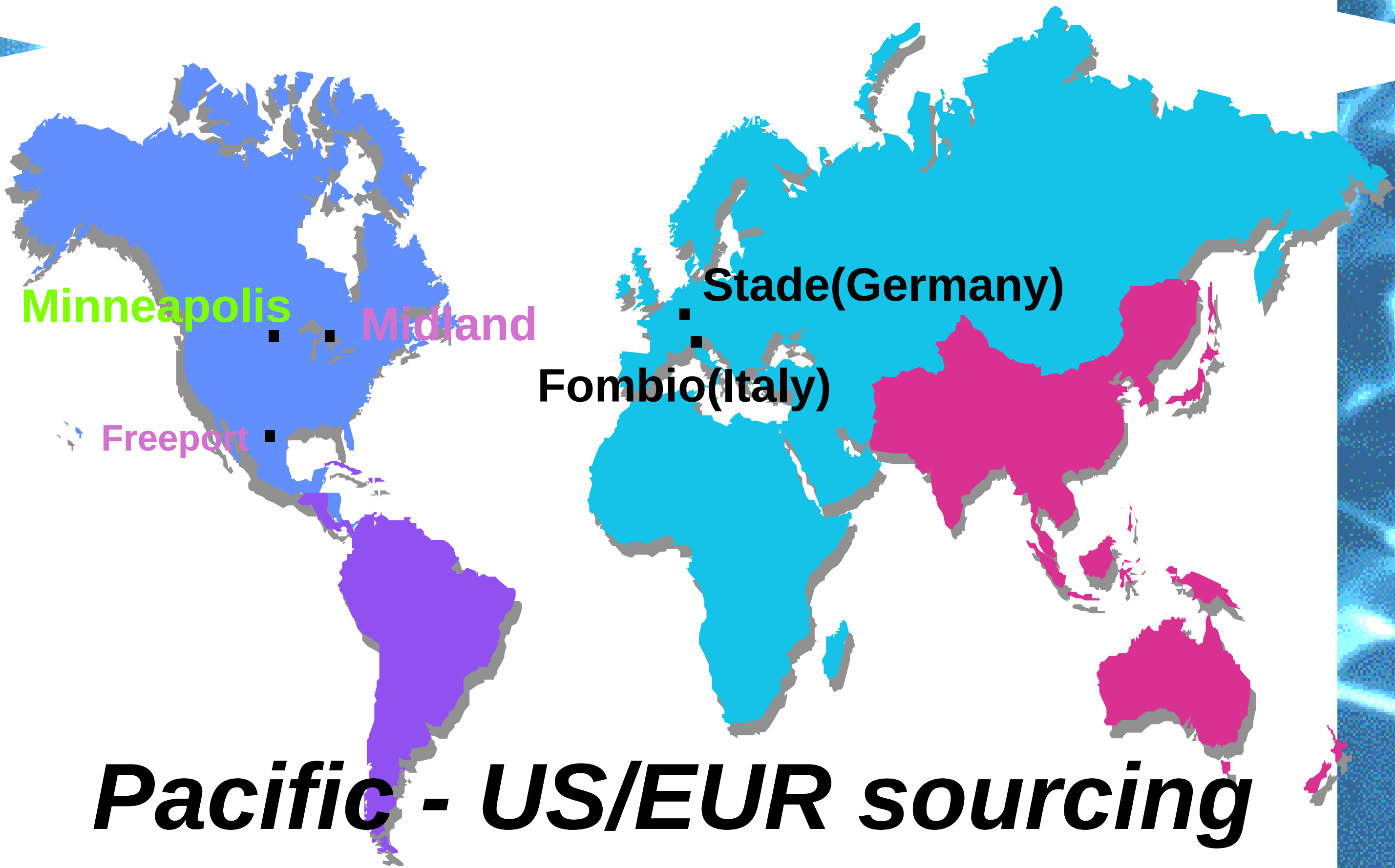
Solute	MW	Rejection (%)
Formaldehyde	30	35
Methanol	32	25
Ethanol	46	70
Isopropanol	60	90
Urea	60	70
Lactic acid (pH 2)	90	94
Lactic acid (ph 5)	90	99
Glucose	180	99.8
Sucrose	342	99.8
Chlorinated pesticides		99

FT30 Reverse Osmosis Membrane

Solute	MW	Rejection (%)
Sodium fluoride (NaF)	42	98
Sodium cyanide (NaCN)	49	95
Sodium chloride (NaCl)	58	99
Silica (SiO_2) (50 PPM)	60	98
Sodium bicarbonate ($NaHCO_3$)	84	98
Sodium nitrate ($NaNO_3$)	85	93
Magnesium chloride ($MgCl_2$)	95	98
Calcium chloride ($CaCl_2$)	111	99
Magnesium sulfate ($MgSO_4$)	120	99
Nickel sulfate ($NiSO_4$)	155	99
Copper sulfate ($CuSO_4$)	160	99

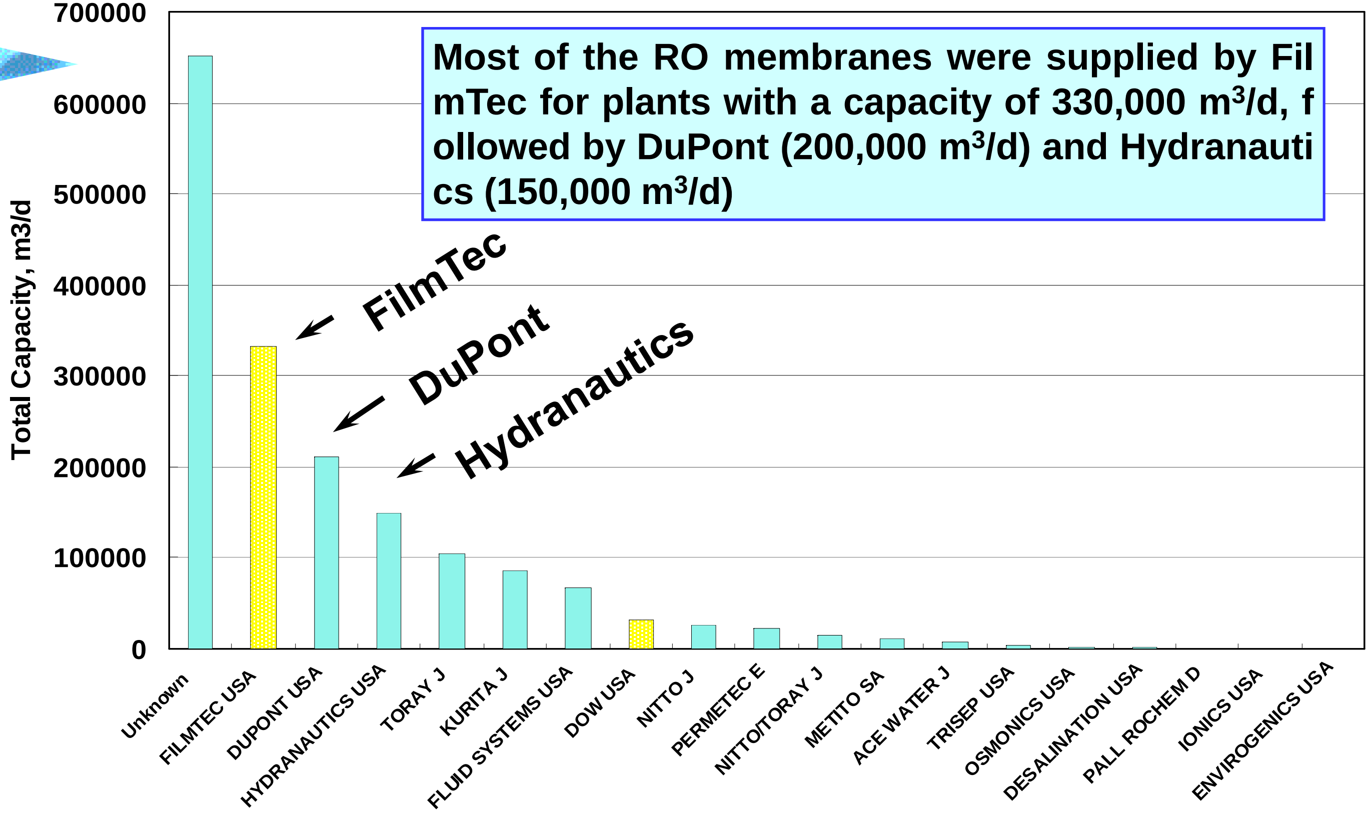
THE DOW LIQUID SEPARATIONS

Manufacturing Sites



Pacific - US/EUR sourcing

CAPACITY of all land-based **RO** and **MS** desalting plants capable of producing 100 (100^3/d)/**UNIT** or more fresh water and contracted 1996 and 1997 vs. **MEMBRANE MANUFACTURER**



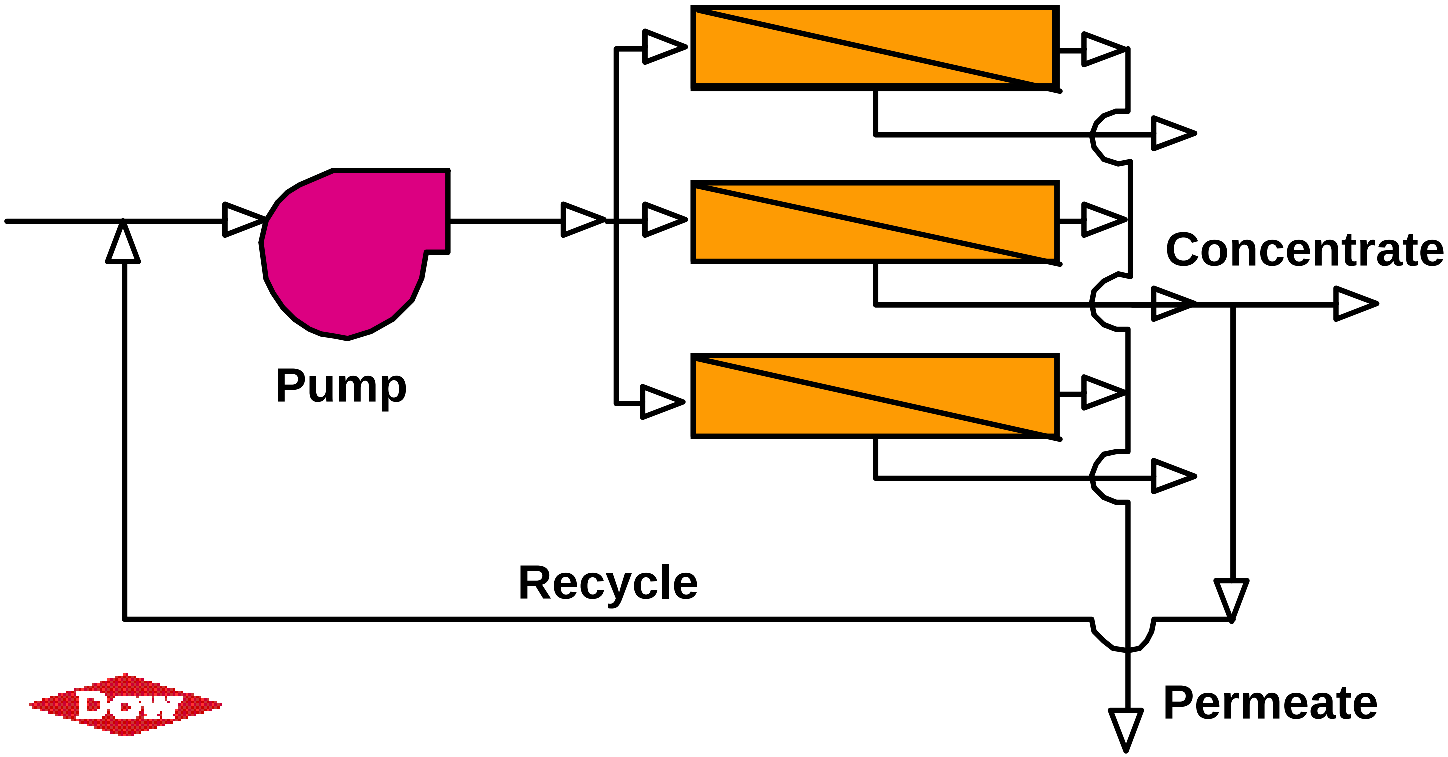
1998 IDA Worldwide Desalting Plants Inventory Report No.15

FILMTEC RO

Configuration Types/Terminology

Array / Stage

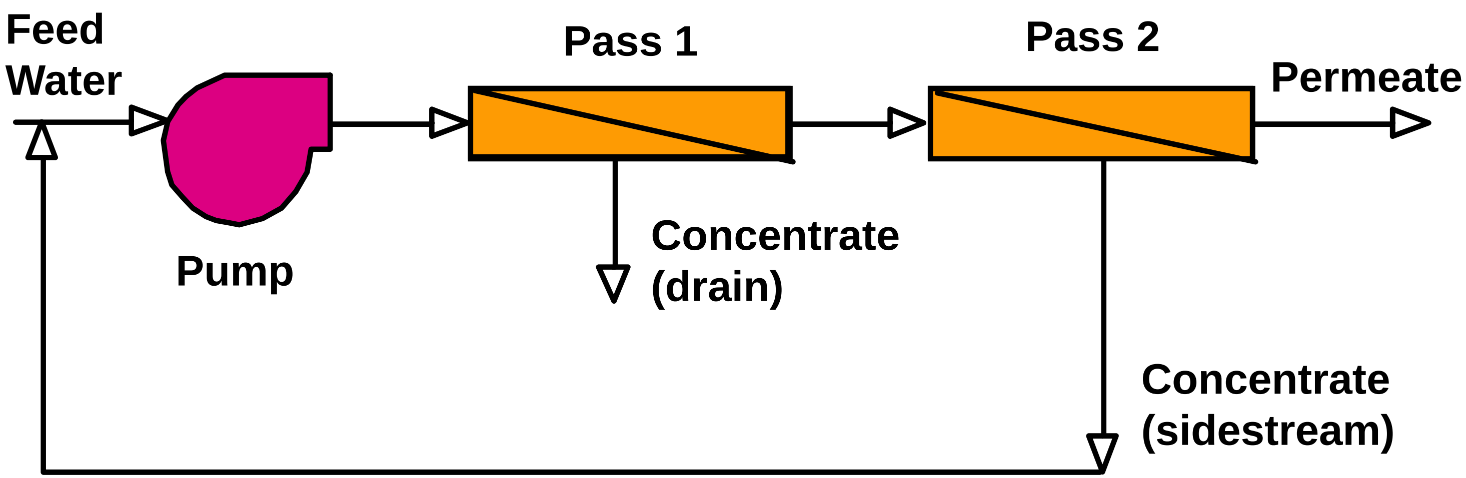
An Array is a series of parallel vessels with common feed, product and reject lines



Configuration Types/Terminology

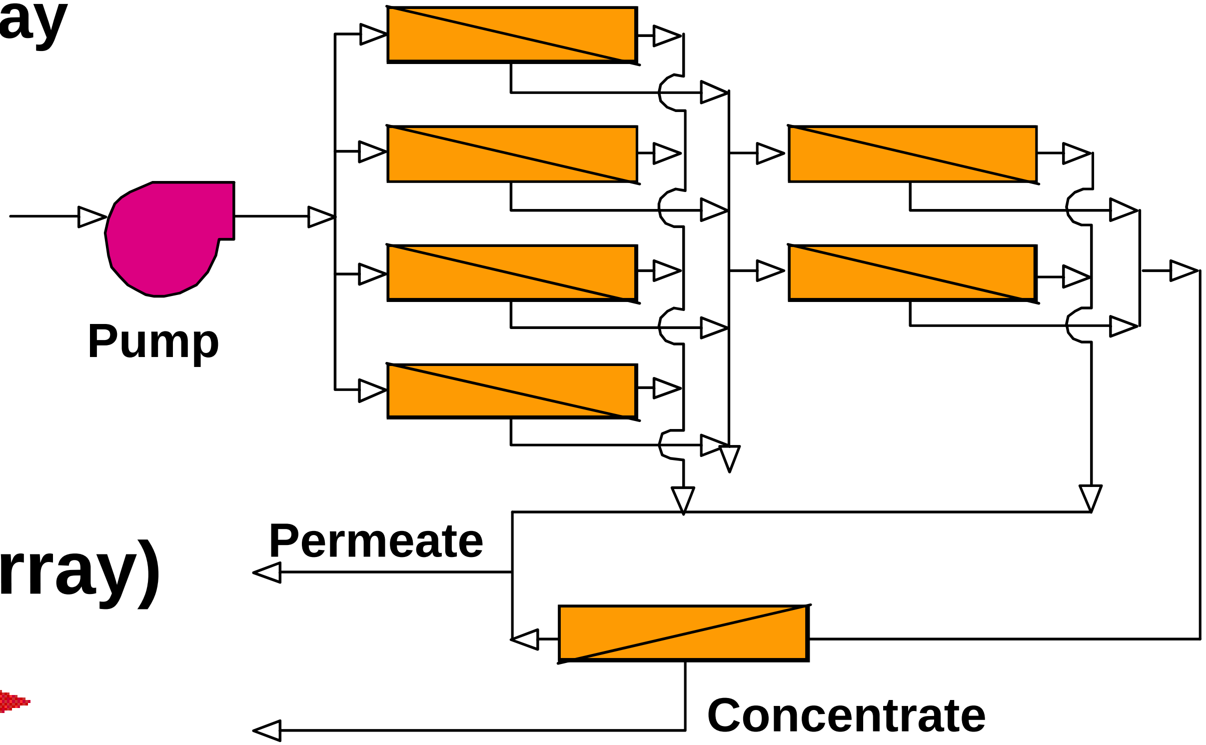
Double-pass = Permeate Staged

Refers to configuration where permeate from first array passes as feed to another array



Multi-Array

- ~85% recovery
- Reject from first array feeds into second array



(3 Array)

Rule of Thumb

- ☞ **100 ppm TDS ≈ 1 psi osmotic pressure (0.07 kg/cm2)**
- ☞ **1,000 ppm TDS ≈ 10 psi osmotic pressure (0.7 kg/cm2)**
- ☞ **35,000 ppm TDS ≈ 350 psi osmotic pressure (7 kg/cm2)**

Mass Balance Equations

$$\text{Recovery (\%)} = \frac{\text{Permeate flow}}{\text{Feed flow}} \times 100$$

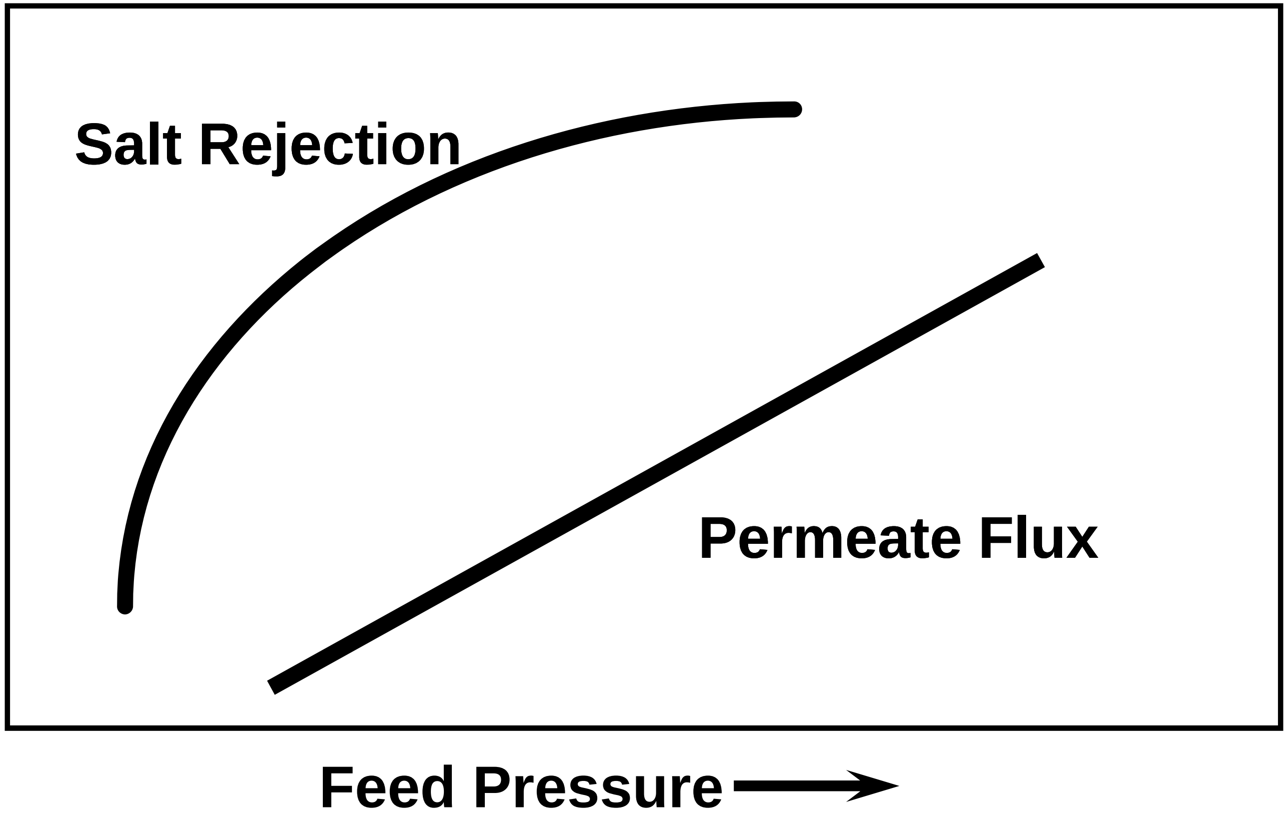
$$\text{Salt Passage (\%)} = \frac{\text{Permeate Salt Concentration}}{\text{Feed Salt Concentration}} \times 100$$

Salt Rejection (%) = 100 - Salt Passage

Factors Which Affect Performance of Membranes

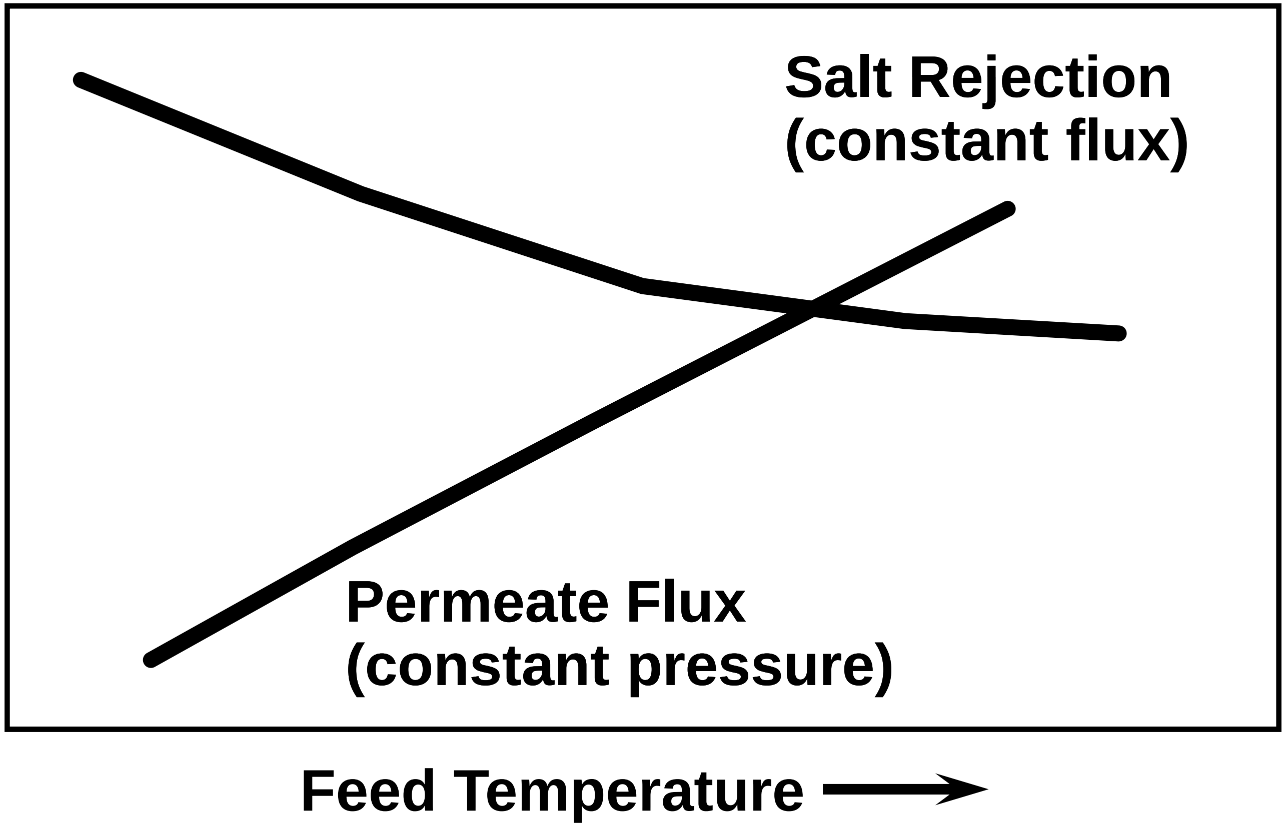
- ☞ **Feedwater pressure**
- ☞ **Feedwater temperature**
- ☞ **Feedwater concentration**
- ☞ **Increased recovery**

Effect of Feedwater Pressure on Flux and Salt Rejection



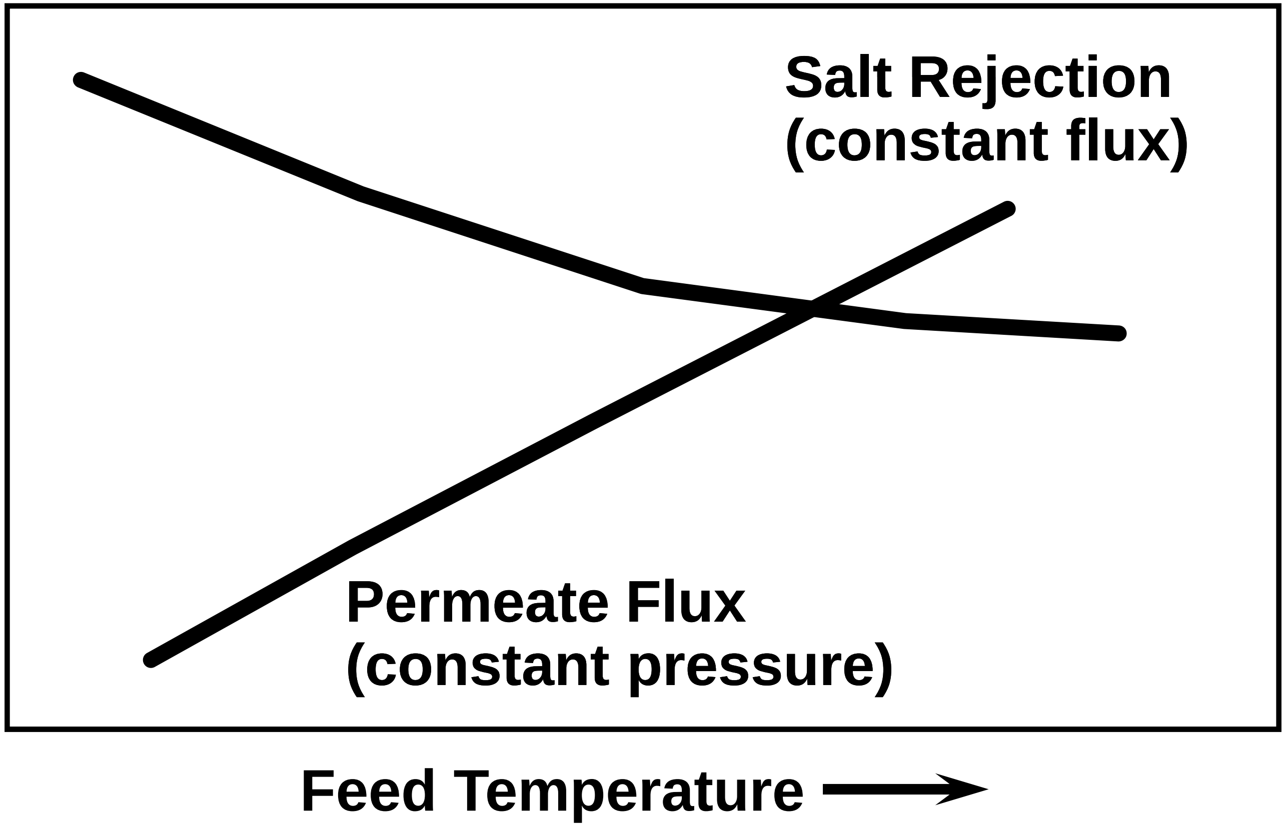
Assuming temperature, recovery and feed concentration are constant

Effect of Feedwater Temperature on Flux and Salt Rejection



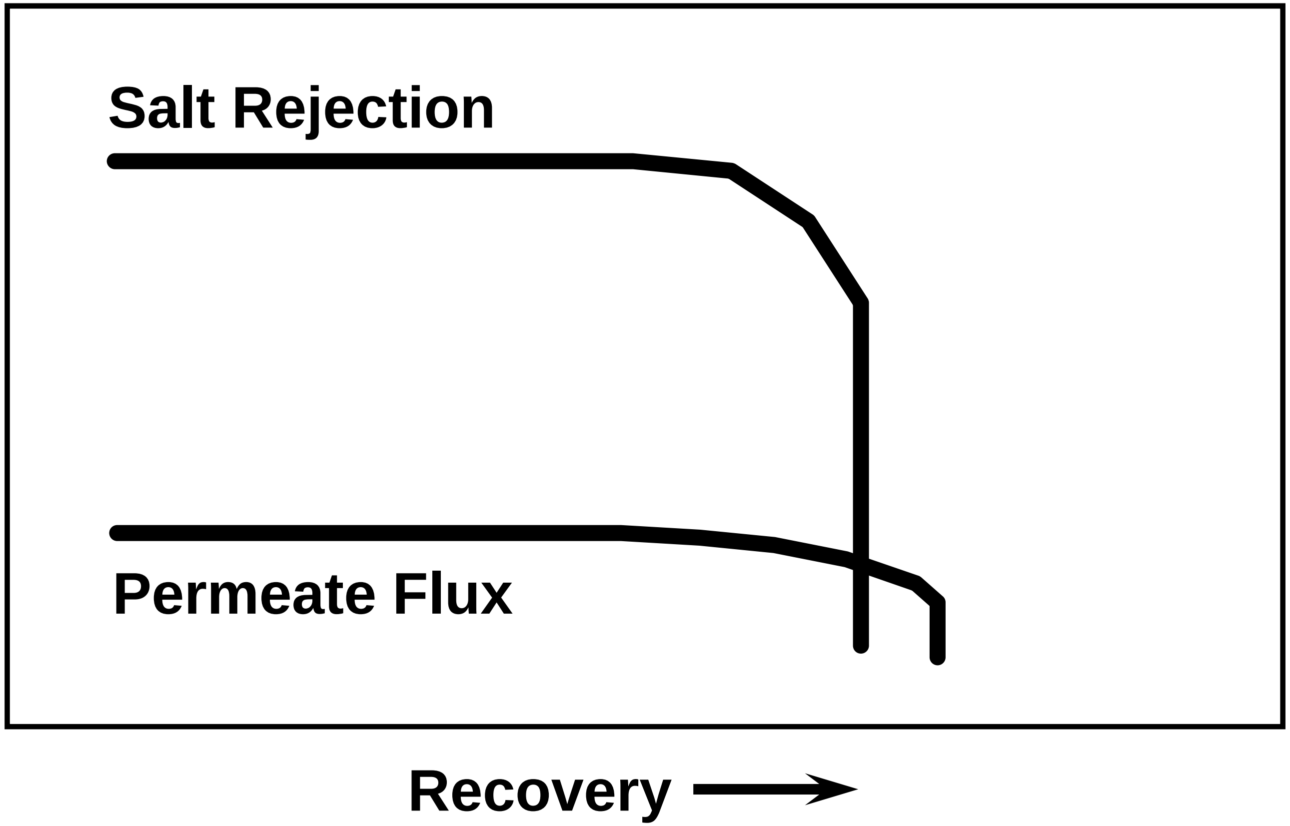
Assuming feed pressure, recovery and feed concentration are constant

Effect of Feedwater Temperature on Flux and Salt Rejection



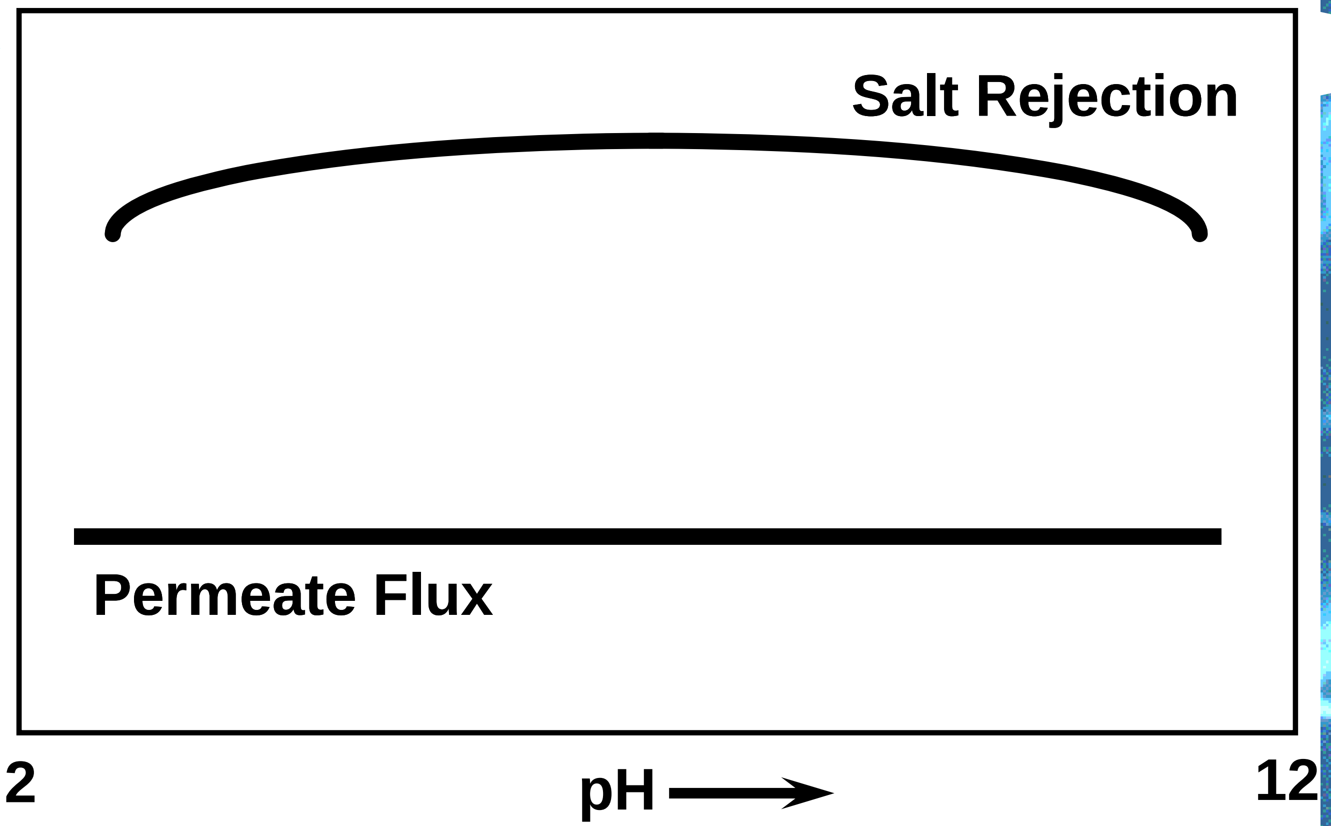
Assuming feed pressure, recovery and feed concentration are constant

Effect of Increased Recovery on Flux and Salt Rejection



Assuming temperature, feed pressure and concentration are constant

Effect of pH on Flux and Salt Rejection



Assuming temperature, recovery, feed concentration and pressure are constant

Advanced RO Design Training

2013-01-07

EVALUATING FEEDWATER SOURCES

- ☞ **Groundwater**
- ☞ **Surface water**
- ☞ **Waste water**
- ☞ **Seawater**

EVALUATING FEEDWATER SOURCES

- **Ground water sources**
  - **Low levels suspended solids**
  - **SDI typically low, < 3.0**
  - **May have dissolved gases like H_2S**
  - **Organic compounds**
    - **Low levels in deep wells**
    - **Higher levels in shallow wells influenced by surface waters**
  - **Stable water temperatures**
  - **Biological activity typically low**

EVALUATING FEEDWATER SOURCES (cont'd)

- **Surface water sources**
  - **Variable levels suspended solids**
  - **SDI typically high, > 3.0, many times > 6.7**
  - **Organic compounds**
    - **Variable levels, seasonly influenced**
    - **Naturally occurring as well as man-made**
  - **Water temperatures variable**
  - **Biological activity is high**

EVALUATING FEEDWATER SOURCES (cont'd)

- **Waste water sources**
  - **Variable levels suspended solids**
  - **SDI typically high, > 3.0, many times > 6.7**
  - **Organic compounds**
    - **Variable levels, seasonly influenced**
    - **Naturally occurring as well as man-made**
  - **Water temperatures variable**
  - **Biological activity is very high**

EVALUATING FEEDWATER SOURCES (cont'd)

- **Seawater sources**
  - **Surface intake or beach wells**
  - **SDI depends on source**
    - **Suface intake > 3.0**
    - **Beach wells < 3.0**
  - **Organic compounds - typically low**
  - **Water temperatures variable (surface intake)**
  - **Biological activity is high (surface intake)**

EVALUATING FEEDWATER SOURCES

- Feedwater information helps determine pretreatment unit operations
- Allows Dow to suggest the right or best element for the application
- Allows Dow to suggest the best design for low cost plus reliable operation

PRETREATMENT CONSIDERATIONS

- **Filtration**
  - **Media filtration**
  - **Microfiltration**
  - **Ultrafiltration**
- **Dechlorination**
- **Scale Control**

PRETREATMENT CONSIDERATIONS

- **Media filtration**
  - **Reduction in colloidal, suspended and particulate material**
  - **SDI utilized to measure filtration effectiveness**
  - **Filters can be single or multi- media**
  - **Coagulants and flocculants sometimes dosed before filters to enhance filtration**

PRETREATMENT CONSIDERATIONS

- **Microfiltration (MF)**
  - **Produces better feedwater quality than media filtration**
  - **Higher capital cost**
  - **May allow for more aggressive RO membrane design**
  - **Expands the choices for RO membranes on difficult-to-treat water applications**

PRETREATMENT CONSIDERATIONS

- **Ultrafiltration (UF)**
  - **Produces better water quality than media filtration or MF**
  - **Higher capital cost**
  - **May allow for more aggressive RO membrane design**
  - **Expands the choices for RO membranes on difficult-to-treat water applications**

PRETREATMENT CONSIDERATIONS

- **Dechlorination**
  - **Granular Activated Carbon (GAC)**
    - **Removes chlorine very well**
    - **Source of bacterial contamination**
    - **Carbon fines**
  - **Sodium Meta-bisulfite (SMBS)**
    - **Reacts quickly with chlorine**
    - **Better choice in warm climates**
    - **Sulfate reducing bacteria**

PRETREATMENT CONSIDERATIONS

- **Scale control**
  - **Antiscalants**
    - **Designed for sulfate and silica scales**
    - **Can be formulated for water sources containing iron or aluminum**
    - **Dow does not approve products**
  - **Mineral acids**
    - **Typically HCl or H_2SO_4**
    - **Sometimes used with antiscalants**
  - **Ion exchange softening**

Other Factors to be Aware of …

- ☞ **Fouling factor concept**
  - – **BW – 1.0 initial to .85 in 3 years**
  - – **SW – 1.0 initial to .8 in 3 years**

Other Factors to be Aware of …
Feed Composition on System Recovery

- Seawater recovery limitations
  - High osmotic pressure
  - Osmotic pressure limits recovery to 35-45%
- Brackish water recovery limitations
  - Brackish water chemistry tends to contain many sparingly soluble salts which cause scaling
  - Usually limits recovery to 70-80%

Feedwater Characteristics After Pretreatment

- ☞ **SDI < 5.0, preferably < 3.0**
- ☞ **Al, Fe, and Mn concentrations $\leq$ 0.05 ppm**
- ☞ **Chlorine residual < 0.1 ppm**
- ☞ **LSI in the brine stream slightly negative or < +1.5 if antiscalant is used to control $CaCO_3$ scale**

General Rule of Troubleshooting

First Stage Problem: Fouling

Last Stage Problem: Scaling

Troubleshooting

☞ **Signs of trouble**

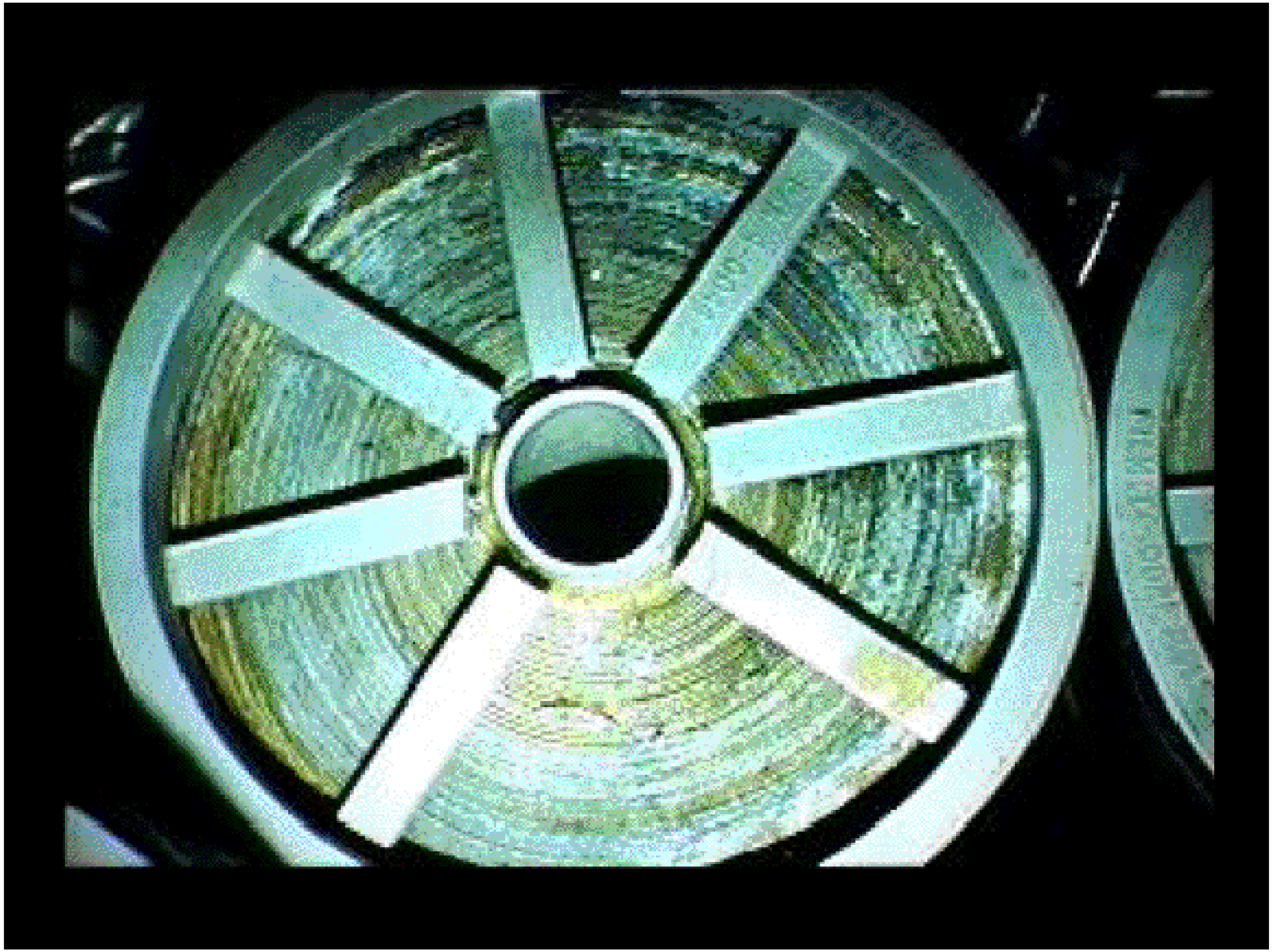
– **Loss of permeate flow**

– **Increase in salt passage**

– **Increase in ΔP**

Calcium Carbonate Scaling

- ☞ **Most common precipitate**
- ☞ **Becomes less soluble at high temperatures**
- ☞ **Scaling caused by hardness, high pH, high alkalinity and high recovery rates**



Langelier Saturation Index
Stiff and Davis Stability Index

- **Measure of $CaCO_3$ scaling potential**
- **Standard ASTM procedures**
- **LSI**
  - **Feedwater with TDS < 10,000 mg/l**
  - **Typical limits**
    - **FILMTEC FT30: + 1.5 with antiscalant**
      < 0.0 without antiscalant
- **S&DSI**
  - **Feedwater with TDS >10,000 mg/l**

Calcium Carbonate Pretreatment

- ☞ **Antiscalant injection**
- ☞ **Acid injection**
- ☞ **Cation softening**
- ☞ **Lime softening**
- ☞ **Limit recovery**

Sulfate Scaling

- Solubility of sulfate salts increases as the ionic strength increases
  - Barium
  - Strontium
  - Calcium

Sulfate Pretreatment

- Antiscalant injection
- Cation softening
- Lime softening
- Limit recovery

Calcium Fluoride Scaling

- CaF_2 solubility increases as temperature increases

Pretreatment

- Antiscalant injection
- Cation softening
- Lime softening
- Limit recovery

Silica Scaling

- **Solubility is dependent on pH, temperature, total alkalinity and SiO_2 concentration**
- **When supersaturated can form insoluble colloidal silica**
- **Solubility decreases in the presence of Al or Fe. Ensure absence of Al and Fe in feed.**

Silica Pretreatment

- Lime softening for systems > 5,000 m^3/day
- Increase feed temperature
- Increase pH to > 8
- Reduce recovery

Fouling

- ☞ Biological
- ☞ Organic
- ☞ Colloidal
- ☞ Silt
- ☞ Metal oxide
- ☞ Carbon

Biological Fouling

- Common in surface feedwater
- Microbes adhere to membrane surface and form biofilm
- Fouling caused by
  - Improper membrane preservation
  - Biological material in feedwater
  - Improper carbon bed maintenance

Biological Pretreatment

- Chlorination
  - Feed must be dechlorinated to protect membranes
- Shock treatment
- Ozone
- Granular activated carbon

Organic Fouling

- Humic substances occur in concentrations between 0.5 and 20 mg/l TOC
  - Pretreat when TOC exceeds 3 mg/l
- High molecular mass compounds that are hydrophobic or cationic

Colloidal Fouling

☞ **Foulants of concern**

- **Silica**
- **Fe_2O_3**

☞ **Determined by SDI test**

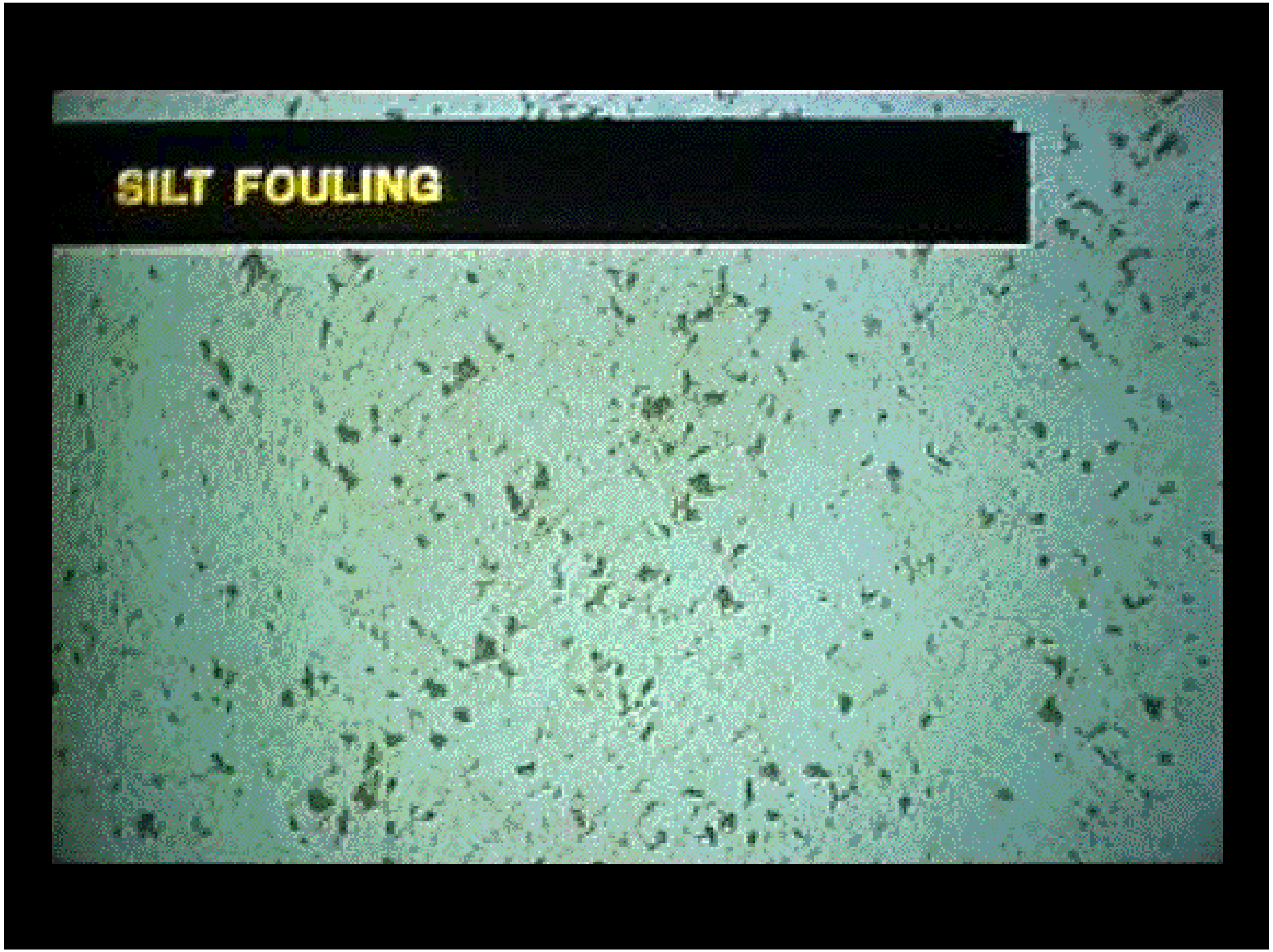
☞ **Consider pretreatment if SDI is > 3.0**

Colloidal Pretreatment

- **Ultrafiltration**
- **Media filtration if SDI is $\geq$ or equal to 6**
- **In-line filtration if SDI is very high, then use coagulation-flocculation**

Silt Fouling

- Caused by dirty surface water (particle laden water) with high SDI
- Pretreat with media filter and/or cartridge filter
- Want SDI < 5; preferably < 3


SILT FOULING

Metal Oxide Fouling

- ☞ **Iron**
- ☞ **Aluminum**
- ☞ **Manganese oxides**

Iron Fouling

☞ **Caused by**

– **Rusty well casings or piping**

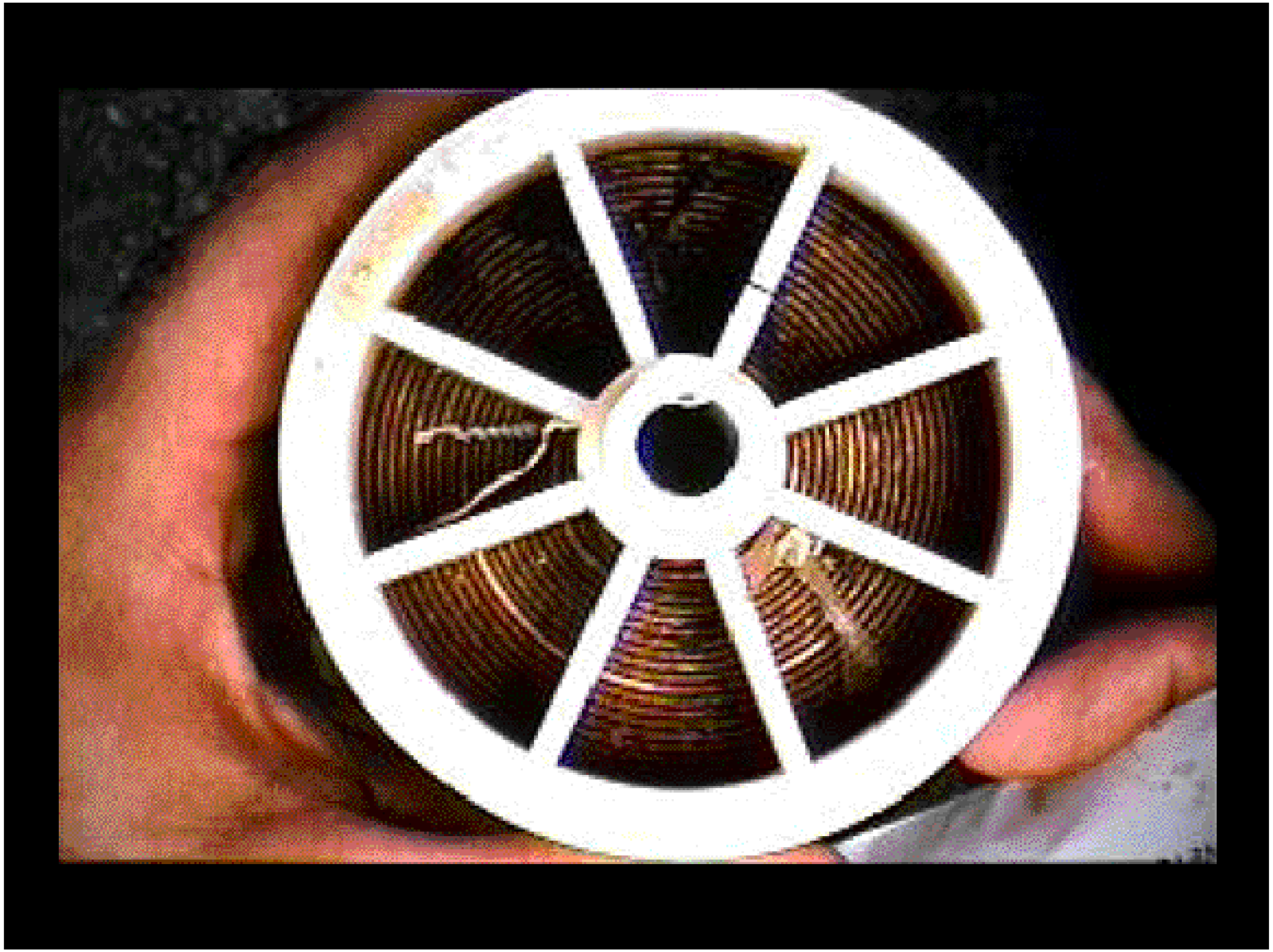
– **> 0.1 ppm Fe in feedwater**

Pretreatment

– **Oxidation to ferric state, then filtration**

– **Cation softening**


IRON FOULING



Aluminum Fouling

- ☞ **Municipalities may add alum to water**
- ☞ **Precipitation of aluminum hydroxide from acid injection**

Pretreatment

- **Minimum solubility occurs at pH 6.5-6.7**
- **Coagulation followed by media filtration**
- **Concentration after pretreatment should be $\leq$ 0.05 mg/l**

Manganese Oxide Fouling

- Usually present as MnO_2

Pretreatment

- **Oxidation ?filtration**
- **Concentration after pretreatment $\leq$ 0.05 mg/l**

Carbon Fouling

- **Caused by**
  - **Inadequate flushing of carbon bed**

Pretreatment

- **Backwash and rinse carbon filter**


CARBON FOULING

Membrane Degradation

- Damage is irreversible
- Oxidation of thin-film layer
  – Caused by chlorine, ozone, potassium permanganate, sodium or calcium hypochlorite
- Hydrolysis of the thin-film layer
  – Caused by high concentration of caustic (pH >13 during cleaning)

DOW

Membrane Degradation Pretreatment

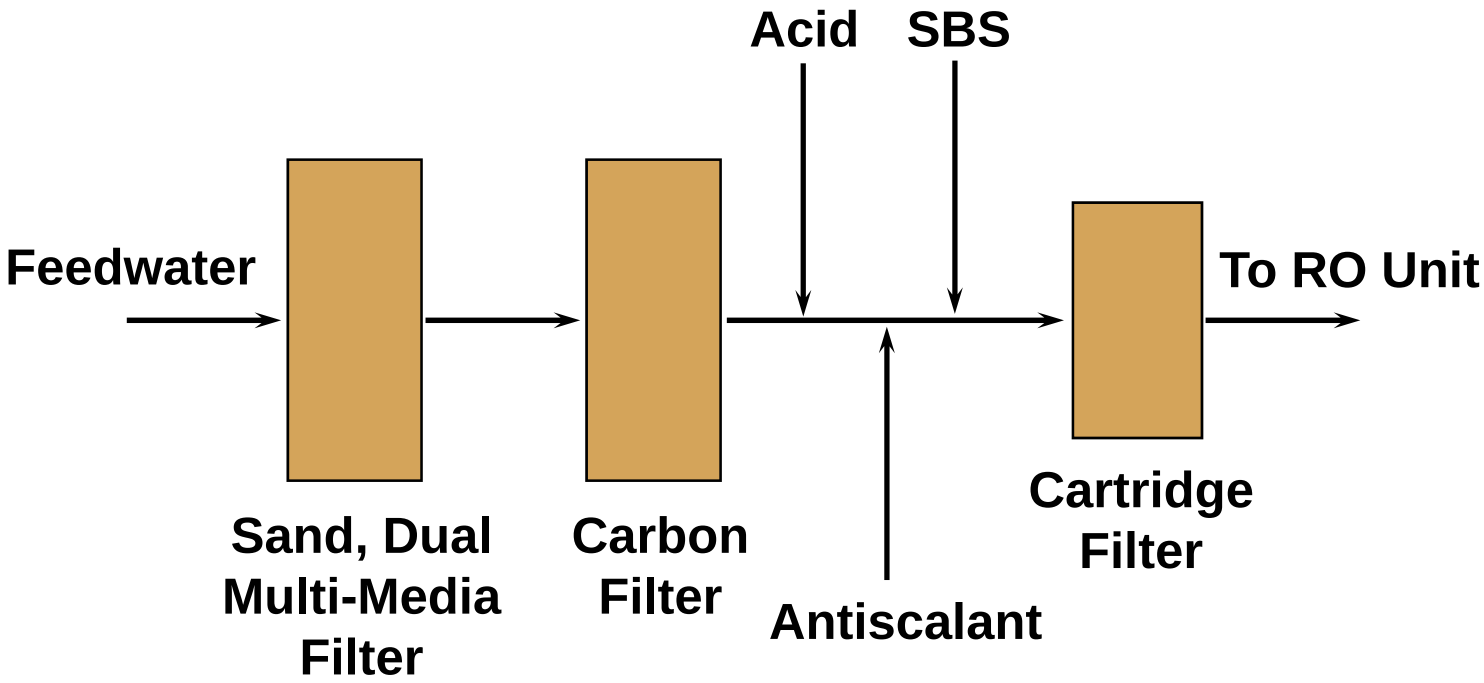
☞ **Oxidation**

- **SBS injection**
- **Carbon filter**

☞ **Hydrolysis**

- **Limit NaOH concentration to 0.1% keeping temperature < 30캜**

Typical Pretreatment Flow Diagram



When to Clean

- ☞ **Normalized flow declines by 10%**
- ☞ **Pressure drop increases by 15%**
- ☞ **Normalized salt passage increases by 5%***

***Dependent on individual system design**

Determining Foulant or Scalant

- Analyze the normalized plant performance
- Analyze feedwater
- Check performance after previous cleanings
- Analyze cartridge filter
- Inspect feed line tubing and feed end scroll
- Inspect scroll of tail element for scaling
- Clean and analyze cleaning solutions
- Destructive autopsy

pH Range and Temperature Limits During Cleaning

	Max Temp 50캜 pH Range	Max Temp 35캜 pH Range	Max Temp 30캜 pH Range	Continuous Operation
SW30/SW30HR	**3 - 10**	**2 - 11**	**2 - 11.5**	**2 - 11**
BW30/TW30	**2 - 10**	**1 - 11**	**1 - 11.5**	**2 - 11**
NF45	**3 - 10**	**2 - 11**	**2 - 11**	**3 - 10**
NF70	**3 - 10**	**2 - 11**	**1 - 11**	**3 - 9**

FT30 Resistance to Cleaning Agents

Agent	% Concentration	Resistance
Hydrochloric Acid*	0.2	Excellent
EDTA*	1.0	Excellent
Sodium Hydroxide*	0.1	Excellent
Nitric Acid	5.0	Excellent
Acetic Acid	5.0	Excellent
Boric Acid	5.0	Excellent
Phosphoric Acid	0.5	Excellent
Sodium Salt of Dodecylsulfate	0.05	Excellent
Sodium Lauryl Sulfate	0.05	Excellent
Sodium Hydrosulfite	1.0	Excellent
Trisodium Phosphate (TSP)	1.0	Excellent
Sodium Triphosphate (STP)	1.0	Excellent

*Most common agents used

Calcium Carbonate Scaling

- **Causes**
  - **Hardness**
  - **High pH**
  - **High alkalinity**
  - **High recovery rates**

- **Symptoms**
  - **Heavy element**
  - **Low permeate flow**
  - **Poor salt rejection**
  - **High pressure drop**

Calcium Carbonate Scaling

- Cleaning
  - 0.2% (Wt) HCl
  - 2.0% (Wt) Citric Acid
  - 0.5% (Wt) $H3PO_4$
  - 0.2% (Wt) sulfamic acid and NH_2SO_3H

Sulfate Scaling

- **Causes**
  - **Exceeding solubility limits**
  - **Loss of antiscalant**
  - **High recovery rates**
- **Symptoms**
  - **Heavy element**
  - **High pressure drop**
  - **Poor salt rejection**
  - **Low permeate flow**

Sulfate Scaling

☞ **Cleaning**

– **Very difficult to clean**

– **1.0(Wt)% Na-EDTA and 0.1(Wt)% NaOH at pH12, 30캜 maximum**

☞ **Overnight soak may be necessary**

Biological Fouling

- Causes
  - Improper membrane preservation
  - Biological material in feedwater
  - Improper carbon bed maintenance
- Symptoms
  - Odor
  - Moldy or discolored scroll end
  - Low permeate flow
  - Superior salt rejection
  - High pressure drop

Biological Fouling

- Cleaning (best method)
  - 0.1% (Wt) NaOH and 0.5% - 1.0% (Wt) Na-EDTA
  - At pH 12 and < 30캜 (86캟)
- Cleaning (alternate method)
  - 0.1% (Wt) NaOH and .05% Na-DDS at pH 12 and < 30캜 (86캟)
  - 1.0% (Wt) STP and 1.0% (Wt) Na-EDTA or 1.0% (Wt) TSP and 1.0% (Wt) Na-EDTA

Iron Fouling

- **Causes**
  - **Rusty well casings or piping**
  - **Greater than 0.1 ppm Fe in feedwater**
- **Symptoms**
  - **Rust coloring on scroll end or ATD***
  - **Rusty colored reject upon start-up**
  - **Low permeate flow**
  - **Poor salt rejection**

***Anti-telescoping device**

Iron Fouling

- Cleaning
  - 1.0% (Wt) sodium hydrosulfite (best)
  - 0.5% (Wt) phosphoric acid
  - 0.2% (Wt) HCl

Silt Fouling

- **Causes**
  - **Dirty surface waters**
  - **High SDI**
  - **Inadequate pretreatment**
- **Symptoms**
  - **Brown or dirty scroll end**
  - **Low permeate flow/poor salt rejection (early stage)**
  - **High permeate flow/very poor salt rejection (later stage)**

Silt Fouling

☞ **Cleaning**

- **Difficult to clean**
- **Caustic and EDTA**
- **Detergent**

Carbon Fouling

- **Causes**
  - **Inadequate flushing of carbon bed**
  - **Soft carbon**
- **Symptoms**
  - **Black deposits on scroll end**
  - **Low permeate flow (early stage)**
  - **High permeate flow/very poor salt rejection (later stage)**

Carbon Fouling

☞ **Cleaning**

- **Very difficult to clean**
- **Detergent**

Chemical Attack

- **Causes**
  - **Incomplete dechlorination (oxidation)**
  - **Exposure to strong oxidant (i.e. permanganate)**
  - **Prolonged exposure to pH extremes (hydrolysis)**
- **Symptoms**
  - **Very high permeate flow**
  - **Very poor salt rejection**
- **Damage irreversible, elements must be replaced**

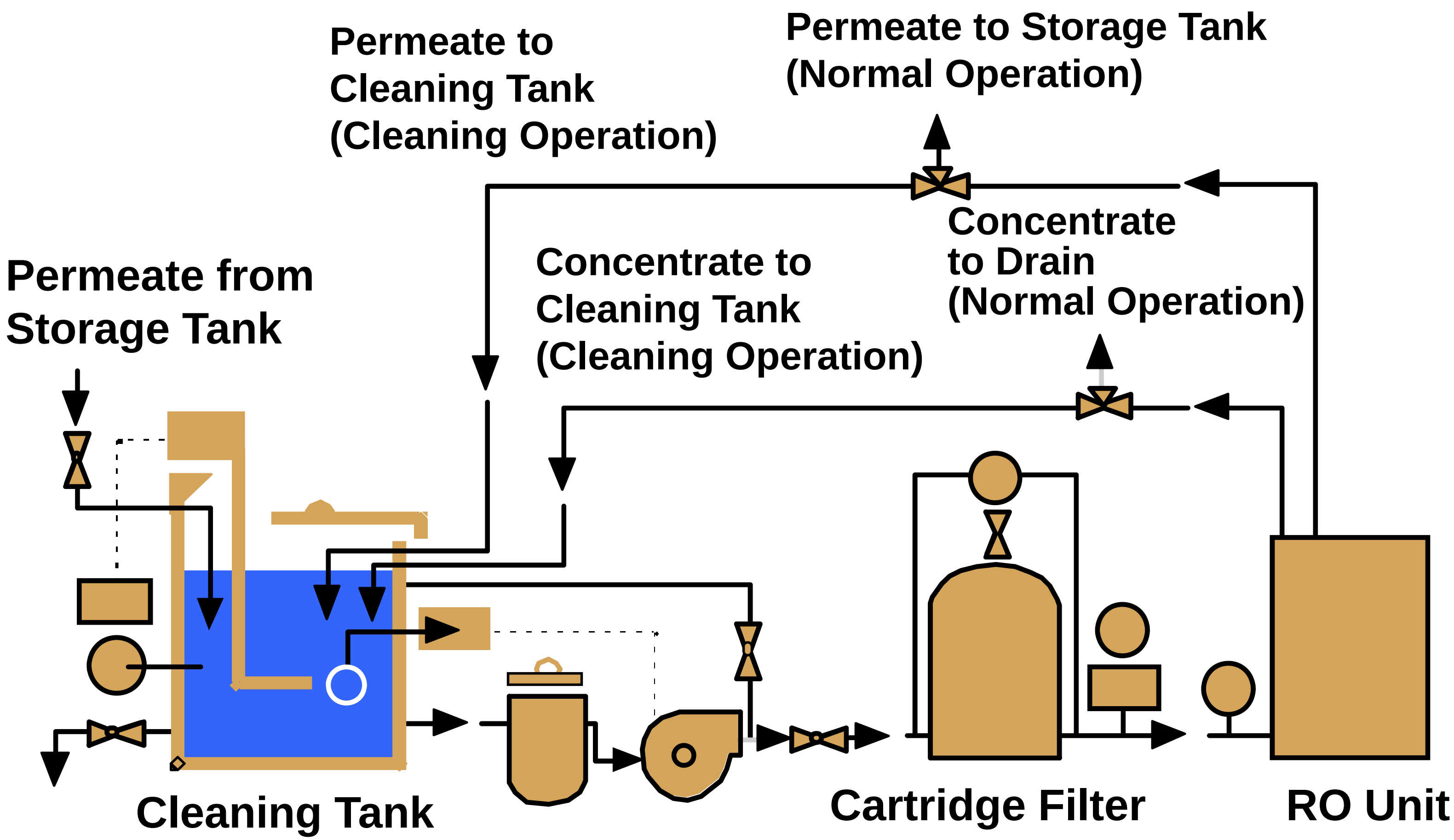
Permeate Backpressure Damage

- **Causes**
  - **Mechanical failure in system**
  - **Poor design or operation error**
- **Symptoms**
  - **High permeate flow and very poor rejection**
  - **Wrinkles in membrane near back glue line**
- **Damage irreversible, elements must be replaced**

Cleaning Process Steps

- Mix cleaning solution
- Low flow pumping (low psi)
- Recycle
- Soak
- High flow pumping (low psi)
- Flush out

Cleaning System



Handling & Preservation

- Standard preservative solution:
  - 1% sodium bisulfite ?Food Grade
  - 18% propylene glycol

Storage Requirements

- **Temperature limits (-4캜 to 45캜) (22캟 to 113캟)**
- **Inside cool building out of sun**
- **In original packaging if possible**

Storage Requirements (Cont뫁)

☞ **Dry Elements**

– **Not affected by temperatures below -4캜 (22캟)**

– **Storage time unlimited**

Storage Requirements (Cont뭗)

☞ **Wet Elements**

– **Inspect for biogrowth every three months**

– **Spot check pH of solution every three months**

☞ **Represerve if it drops below 3**

Low Permeate Flow

1. **Normal salt passage**
   Causes: Biofouling
   Old preservative solution
   Incomplete wetting
2. **High salt passage**
   Causes: Colloidal fouling
   Metal oxide fouling
   Scaling
3. **Low salt passage**
   Causes: Membrane/Element Compaction
   Organic fouling

Low Permeate Flow / Normal Salt Passage

- Cause: Biofouling
  - Improper pretreatment or a change in the feedwater
- Corrective Measures:
  - Clean and disinfect <u>entire</u> system and elements
  - Correct pretreatment

Low Permeate Flow / Normal Salt Passage

- Cause: Old Preservative Solution
  - Too old, too warm or oxidized solution can allow biological fouling

- Corrective Measure:
  - Restore elements through alkaline cleaning or SBS soak [1% (w)]

Low Permeate Flow / Normal Salt Passage

- **Cause: Incomplete Element Wetting**
  - **Membrane of improperly stored elements may lose water permeability**
- **Corrective Measures:**
  - **Product Water Pressurization: Close permeate port and pressurize element to 150psi(10k) for 30 minutes. Make sure to re-open permeate port <u>before</u> releasing feed pressure, otherwise damage to elements can occur**
  - **Soak elements in 1.0% (w) SBS for 1-24 hrs**
  - **Run system continuously for 1 week to see if flux returns to initial rate**

Low Permeate Flow / High Salt Passage

This is the most commonly occurring condition for system failure.

Cause: Colloidal Fouling

Common colloidal fouling sources

- **Feedwater: silica, silt, clay, etc.**
- **Piping material composition**

Low Permeate Flow / High Salt Passage

Cause: Colloidal Fouling

To identify colloidal fouling

- **Check SDI of feedwater**
- **Check SDI filters for deposits**
- **Check cartridge filters for deposits**
- **Check scroll end of 1st stage lead element for deposits**

Corrective Measures:

- **Clean membranes**
- **Correct pretreatment**

Low Permeate Flow / High Salt Passage

Cause: Metal Oxide Fouling

- **Predominently in first array**
- **Common sources for fouling**
  - ☞ **Iron or aluminum in feedwater**
  - ☞ **Piping, vessels, or components upstream of membranes**
    - **Corrosion may occur if pH is low**

Low Permeate Flow / High Salt Passage

Cause: Metal Oxide Fouling

To identify metal oxide fouling

- **Check feedwater analysis for iron/aluminum**
- **Check system materials upstream of membranes**

Corrective Measure:

- **Clean membranes**
- **Correct pretreatment**
- **Adjust pH throughout system**
- **Retrofit piping or system components**

Low Permeate Flow / High Salt Passage

Cause: Scaling

- **Usually occurs in last array**

To Identify:

- **Check feedwater analysis (soluble salts, pH, LSI (S&DSI for seawater)**
- **Check concentrate pH and soluble salts**

Low Permeate Flow / High Salt Passage (Cont뮌.)

Cause: Scaling

Corrective Measures:

- **Clean with acid and/or alkaline EDTA solution and analyze spent solution**
- **Optimize cleaning depending on scaling salts found**
  - ☞ **For carbonate scaling: lower pH, adjust antiscalant dosage**
  - ☞ **For sulfate scaling: lower recovery, adjust antiscalant type or dosage**
  - ☞ **For fluoride scaling: lower recovery, adjust antiscalant dosage**

Low Permeate Flow / Low Salt Passage

Cause: Membrane/Element Compaction

- **Excessive feed temperature or pressure (Membrane)**
- **Water hammer ?which occurs when pump is started with air in the system (Element)**

Corrective Measure:

- **Damaged elements must be replaced**
- **Add additional elements to tail-end of system**

Low Permeate Flow / Low Salt Passage

Cause: Organic Fouling

- **High molecular weight organics**
- **Hydrophobic or cationic group organics such as oil traces and cationic polyelectrolytes**

To Identify:

- **Check filters for deposits**
- **Analyze feedwater**

Low Permeate Flow / Low Salt Passage

Cause: Organic Fouling

Corrective Measure:

- **Some organics can be cleaned successfully; some cannot**
  - ☞ **Cleaning oil is usually not successful**
- **Correct pretreatment**
  - ☞ **Use minimal flocculant dosages**
  - ☞ **Monitor feedwater changes to avoid flocculant overdosing**

High Salt Passage

1. **Normal permeate flow**

   Causes: **Leaking O-ring**, **Surface abrasion**, **Telescoping**, **Permeate backpressure**

2. **High permeate flow**

   Causes: **Membrane oxidation**
   Mechanical damage: massive glue line leak/crack in water tube, adaptor or interconnector/O-ring by-pass

3. **Low permeate flow**

   Causes: **Colloidal fouling**
   Metal oxide fouling
   Scaling

High Salt Passage / Normal Permeate Flow

Cause: Leaking O-ring

- **Probe to determine which O-ring is malfunctioning**

Corrective Measure:

- **Replace old, damaged O-rings**
- **Properly install O-ring**

High Salt Passage / Normal Permeate Flow

☞ **Cause: Telescoping**
- **ΔP too high**
- **Water hammer**
- **Thrust rings out of place**

☞ **Corrective Measures:**
- **Replace damaged elements**
- **Correct operating causes**

High Salt Passage / Normal Permeate Flow

Cause: Membrane Surface Abrasion

- **Carbon fines**
- **Cartridge filter by-pass**

Corrective Measure:

- **Flush carbon filter properly**
- **Adjust cartridge system seal**
- **Replace damaged elements**

High Salt Passage / Normal Permeate Flow

Cause: Permeate Backpressure

- **Occurs when permeate back pressure exceeds feed pressure by 5 psi**

To Identify:

- **Probe to determine damaged elements**
- **Autopsy will show wrinkles in membrane layer due to stretching**

Corrective Measure:

- **Correct excessive back pressure**
- **Replace elements**

High Salt Passage / High Permeate Flow

Cause: Membrane Oxidation

- Chlorine exposure
- Potassium permangenate exposure

To Identify:

- Conduct element autopsy and membrane dye-test

Corrective Measures:

- Correct pretreatment
- Replace elements

High Salt Passage / High Permeate Flow

Cause: Mechanical Damage:

- **Glue line leak caused by excessive permeate pressure**
- **Crack in product water tube, adaptor or interconnectors caused by excessive feed pressure or water hammer**
- **O-ring by-pass caused by a cut in the O-ring, improper placement or non-placement**

To Identify:

- **Probe if one vessel shows significantly higher permeate TDS level**

High Salt Passage / High Permeate Flow (Cont 뮌)

Cause: Mechanical Damage

Corrective Measures:

- **Check system to determine cause of high pressure**
  - ☞ **Sources of back pressure/feed pressure**
  - ☞ **Check valves ?are they leaking?**
- **Correct permeate/feed pressure**
- **Replace elements**
- **Replace adaptors, interconnectors**

High Differential Pressure

ΔP is a measure of the resistance to the hydraulic flow of water through the system. This is very dependent on flow rates through the element brine flow channels and on water temperature

Lead element brine flow channels will show debris, foulants, and scalants

High Differential Pressure

☞ **Causes**

- **Cartridge filter by-pass**
- **Media filter breakthrough**
- **Pump impeller deterioration**
- **Scaling**
- **Brine seal damage / improper placement**
- **Biological fouling**
- **Precipitated antiscalants**

High Differential Pressure

Cause: Cartridge Filter By-pass

- **Filter improperly installed**
  - ☞ **Avoid cellulose-based filters**

Corrective Measure:

- **Properly install cartridge filter**
- **Clean filter housings when replacing filters**

High Differential Pressure

Cause: Media Filter Breakthrough

Corrective Measure:

- **Clean lead element individually with detergent using a reverse flow**
- **Backwash media filter**

High Differential Pressure

Cause: Pump Impeller Deterioration

- **Impeller shavings collect on membrane surface**

Corrective Measure:

- **Clean element individually using a reverse flow**
- **Replace/repair pump**

High Differential Pressure

Cause: Brine Seal Damage or Improper Placement

– **Feed by-passes element; system runs at higher recovery, causing fouling or scaling**

Corrective Measures:

– **Replace brine seal or correct placement**

– **Clean elements**

High Differential Pressure

Cause: Biological Fouling

- **Biofilms are gelatinous creating high flow resistance**

Corrective Measures:

- **Correct pretreatment**
- **Clean elements**
- **Disinfect entire system**

High Differential Pressure

Cause: Precipitated Antiscalants

- Gum-like precipitants caused when polymeric organic antiscalants contact multivalent cations (aluminum) or residual cationic polymer flocculants

Corrective Measure:

- Cleaning is difficult
- Repeated cleaning of alkaline EDTA solution may be successful
- Eliminate antiscalant usage and adjust pH, recovery or soften feed

Taking the Total System Approach

☞ **Troubleshooting Steps**

- **Investigate**
- **Evaluate**
- **Solve**
- **Prevent**

Troubleshooting

- **Investigate entire system**
  - **Review normalized operating data**
  - **Check feedwater quality**
  - **Confirm chemical dose rates**
  - **Calculate material balance**
    - **Calibrate instruments, i.e. flow meters**
  - **Try to localize problems for further in-depth evaluation**

If Source of Problem is Not Identified

- Check conductivities and probe if necessary
- Remove and inspect first element, first stage and last element, last stage
- Look for mechanical damage (torn O-ring, cracked fiberglass)
- Visually inspect system (biogrowth)
- Evaluate elements under standard conditions; send to Filmtec for autopsy if necessary
- Determine effect of first high pH then low pH cleaning
- Analyze cleaning solutions for metals and TOC

If Source of Problem is Still Not Identified

☞ **Conduct a destructive autopsy of the elements**

- **Check for metals and organics on membrane surface**
- **Conduct dye test for oxidative damage to the membrane**
- **Visually examine the element for physical damage (wrinkles, glue line separation, etc.)**