



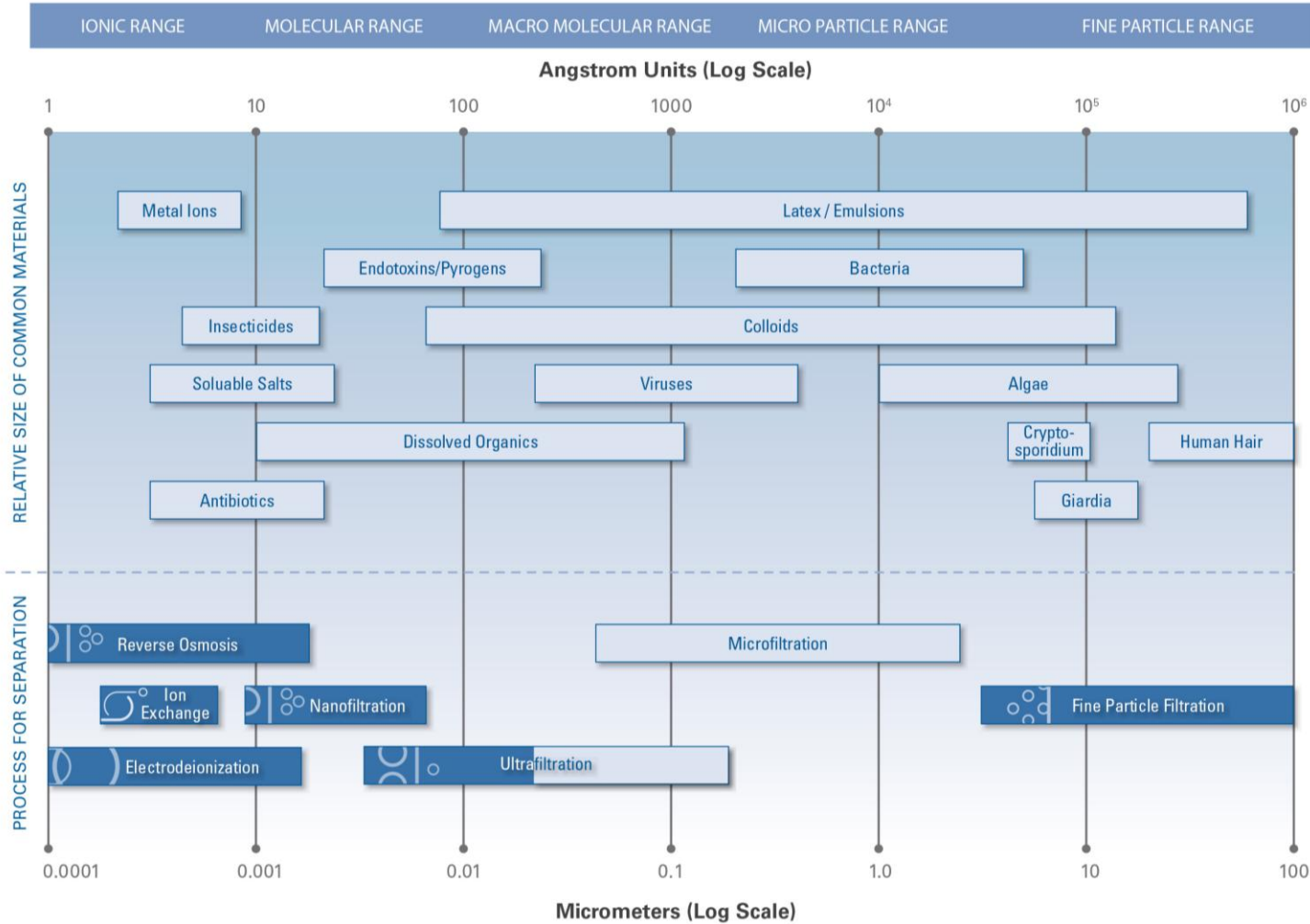
Reverse Osmosis Systems Course Operation & Design

# Content



- Filtration spectrum of membranes
- Basics of Reverse Osmosis and equations
- Factors which affect membrane performance
- Thin Film Composites and Spiral Wound Membranes
- Applications and Markets

# Filtration spectrum

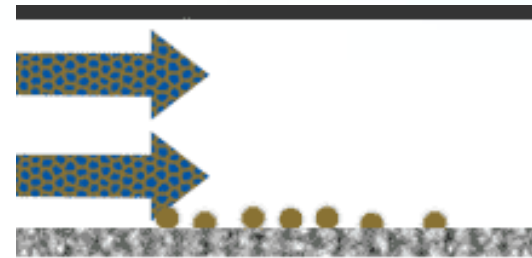
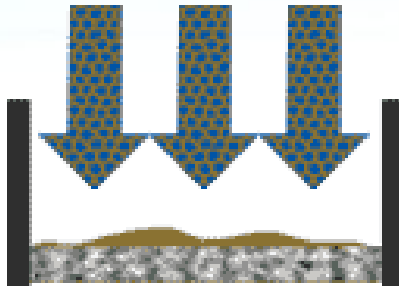


Technology within Dow Water & Process Solutions

®™ Trademark of The Dow Chemical Company ("Dow") or an affiliated company of Dow



# Membrane operation modes



## Dead-end filtration

Not feasible for RO/NF:

- Sparingly soluble salts precipitate and foul the membrane.
- Filter cake build-up

## Cross-flow filtration

Required for RO/NF:

- Sweeps away membrane foulants
- Minimizes concentration polarization
- Generates a concentrate stream and a permeate stream

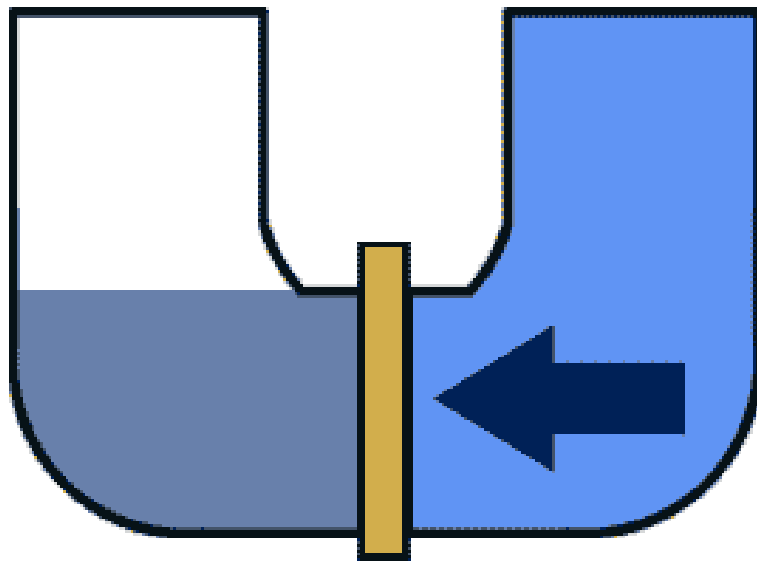


# Typical operating pressures of different pressure driven processes

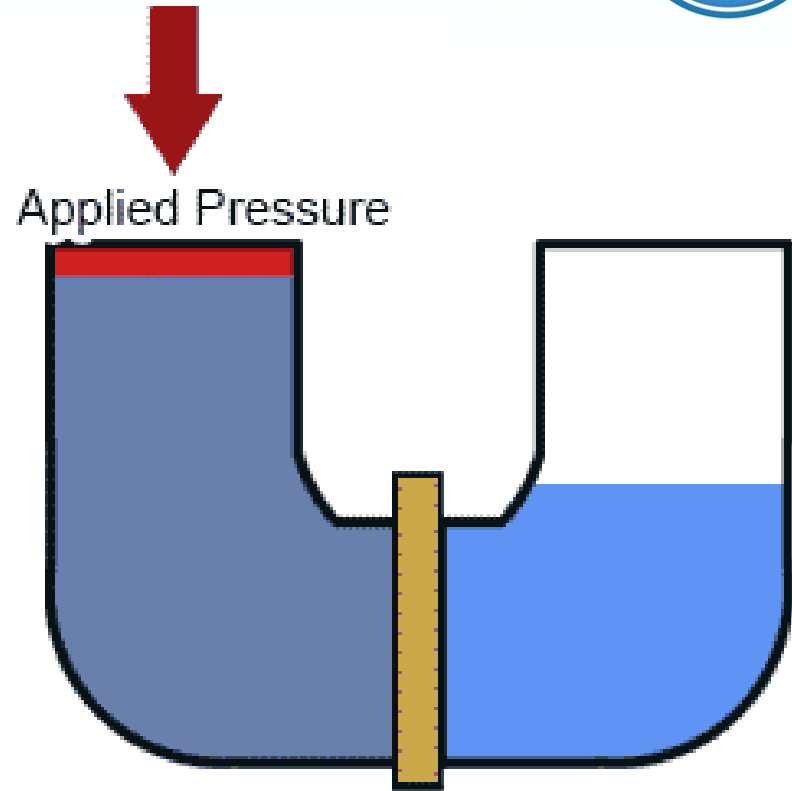


Membrane Process	Typical Operating Pressure Range (bar)	Typical Operating pressure (psi)
Reverse Osmosis Seawater Brackish water	55 – 76 10 - 40	800 - 1100 145 - 580
Nanofiltration	3.5 - 15	50 - 220
Ultrafiltration	2 – 7	30 - 100
Microfiltration	0.1-3	1.5 - 45

# Basics of reverse osmosis

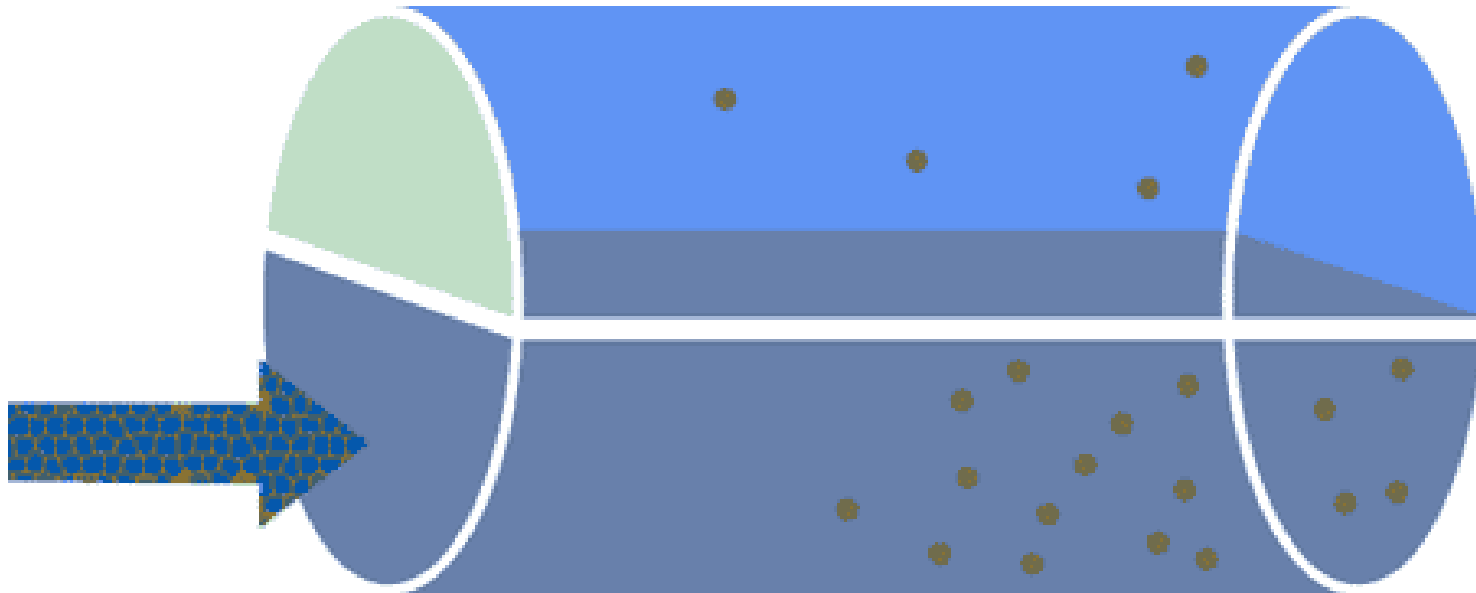


Osmosis



Reverse Osmosis

# Reverse osmosis separation process



# What RO can do?



- ✓ Remove purified water from a feed stream (permeate)
- ✓ Concentrate chemicals in a feed stream (reject)
- ✓ Selectively separate small ions and molecules

# What RO cannot do?



- ✘ Cannot concentrate to 100%
- ✘ Cannot separate to 100%

# Osmotic pressure – rule of thumb



- Convert TDS to osmotic pressure:
  - TDS in ppm divided by 100: osmotic pressure in psi
  - TDS in ppm divided by 1400: osmotic pressure in bar
- Examples:
  - 100 ppm TDS » 1 psi osmotic pressure (» 0.07 bar)
  - 1,000 ppm TDS » 10 psi osmotic pressure (» 0.7 bar)
  - 35,000 ppm TDS » 350 psi osmotic pressure (» 25 bar)



# Osmotic pressure



For dilute solutions, osmotic pressure is approximated using the Van't Hoff equation:

$$\pi = \phi C_i RT$$

$\pi$  - osmotic pressure, atm

$\phi$  - osmotic pressure coefficient

$C_i$  - molar concentrate of the solute, mol/l

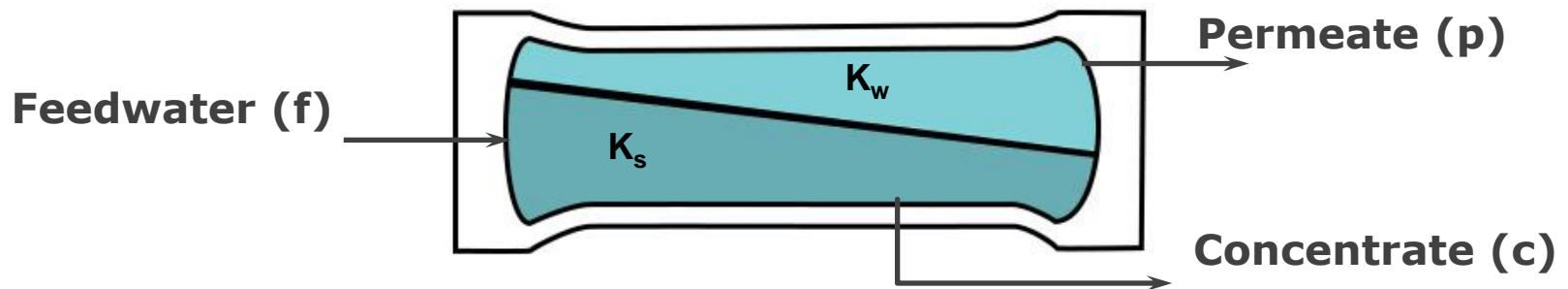
R - gas constant

T - absolute temperature ( ° K)

# Homogenous solution diffusion model



Describes water flux, salt flux and mass-transfer in pressure-driven membrane systems



# Homogenous solution diffusion model



## Water and Solute Flux

$$F_w = K_w (\Delta P - \Delta \pi)$$

- $F_w$  - solvent flux [gallons per square foot per day=gfd]
- $K_w$  - solvent mass transfer coefficient [gfd/psi] (A value)
- $\Delta P$  - transmembrane pressure differential [psi]
- $\Delta \pi$  - osmotic pressure differential [psi]

$$F_s = K_s (\Delta C)$$

- $F_s$  - solute flux [pounds per square foot per day, lbfd]
- $K_s$  - solute mass transfer coefficient [gfd] (B value)
- $\Delta C$  - transmembrane concentration differential [lb/gal]

# Mass balance equations



$$Q_f = Q_p + Q_c$$

$$Q_f C_f = Q_p C_p + Q_c C_c$$

$Q_f$  - feed flow [gal/min]

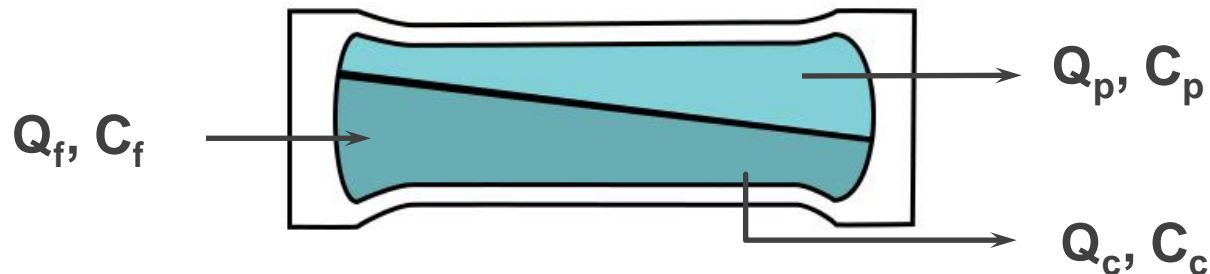
$Q_p$  - permeate flow [gal/min]

$Q_c$  - concentrate flow [gal/min]

$C_f$  - feed solute concentration [lb/gal]

$C_p$  - permeate solute concentration [lb/gal]

$C_c$  - concentrate solute concentration [lb/gal]



# Basic definitions

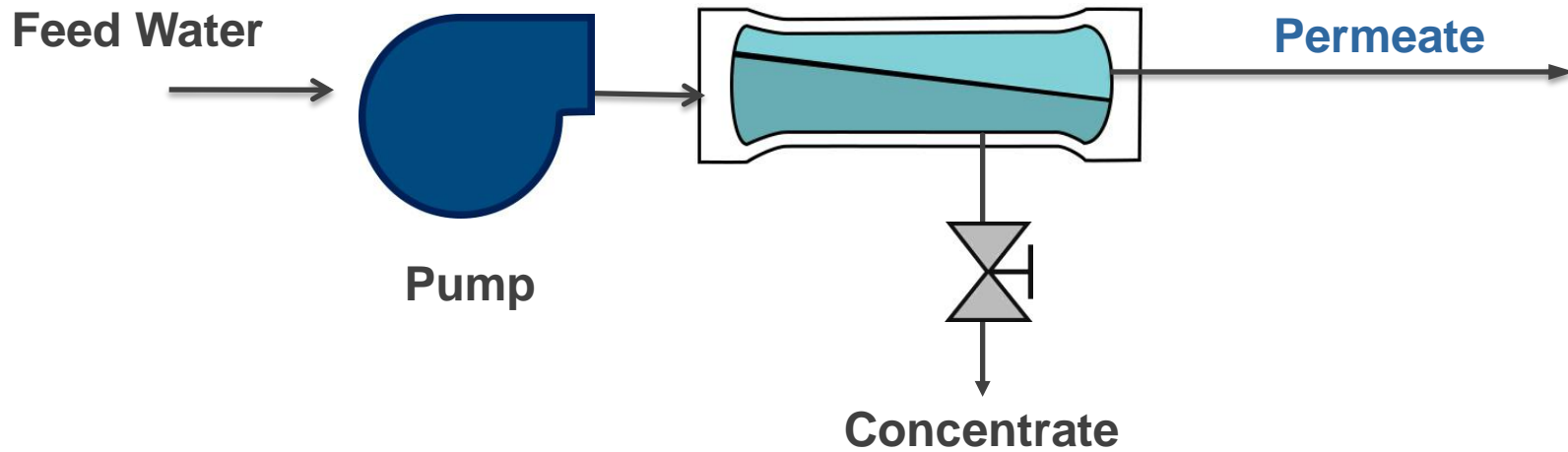


$$\text{Recovery (\%)} = \frac{\text{Permeate flow}}{\text{Feed flow}} \times 100$$

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

$$\text{Salt Rejection (\%)} = 100 - \text{Salt Passage}$$

# Simplified RO system



100 to 600 psi (brackish water)  
800 to 1,200 psi (seawater)

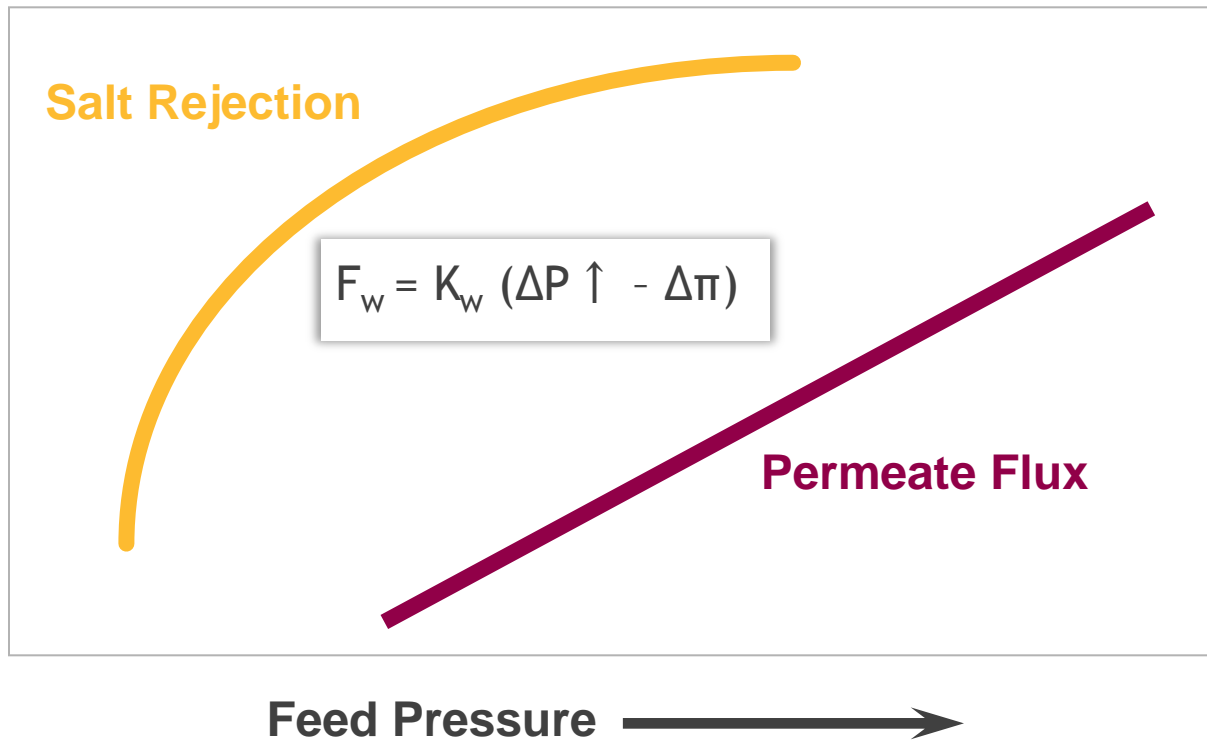


# Factors which effect membrane performance



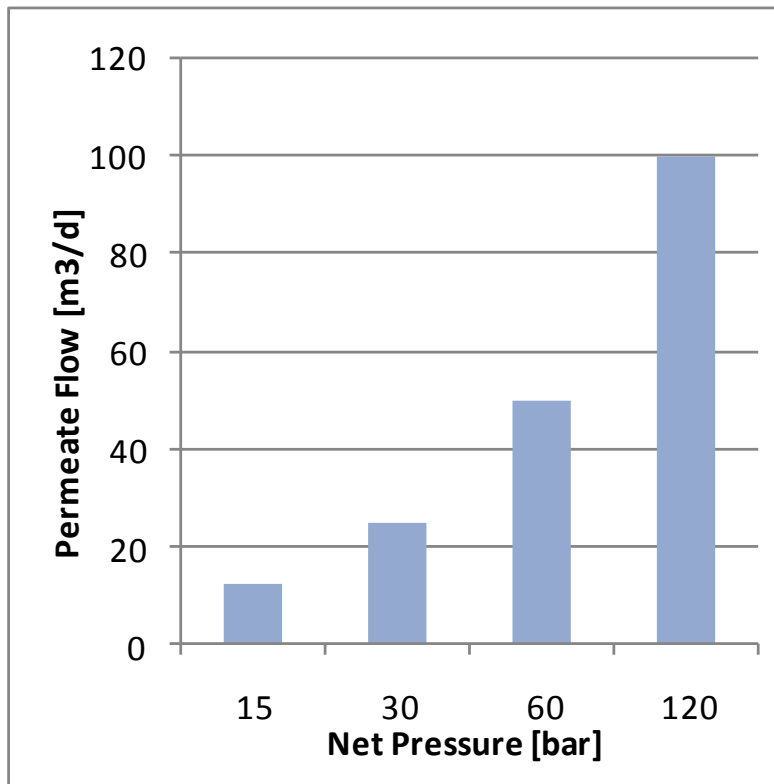
- Feedwater
  - Concentration
  - Temperature
  - Osmotic pressure
  - pH
- Operation parameters
  - Pressure
  - System recovery
- Concentration Polarization

# Affect of feedwater pressure on flux and salt rejection



Assuming temperature, recovery and feed concentration are constant

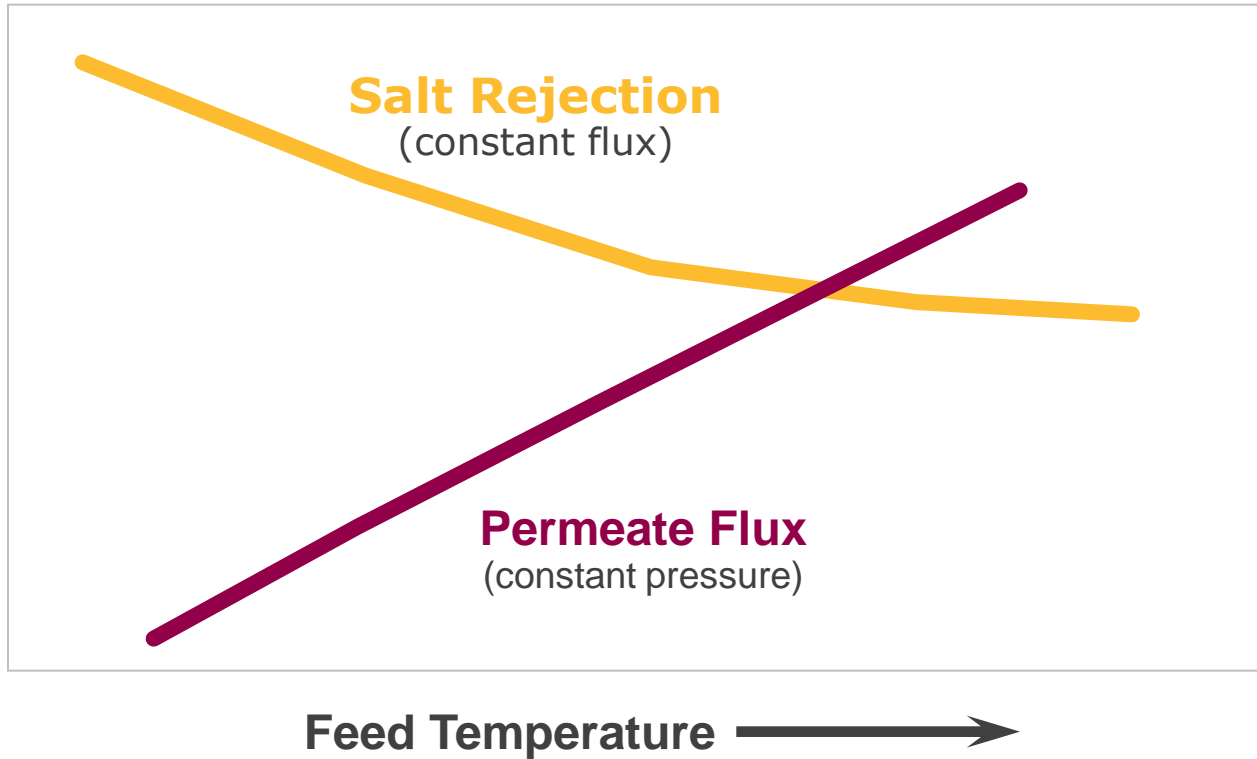
# Pressure Affect



- If you double net driving pressure (NDP) to an RO unit you will double your permeate flow.
- NDP is the sum of all forces acting on the membrane

$$NDP = \Delta P - \Delta \pi$$

# Feedwater temperature vs. flux and salt rejection



Assuming feed pressure, recovery and feed concentration are constant

# Temperature Affect



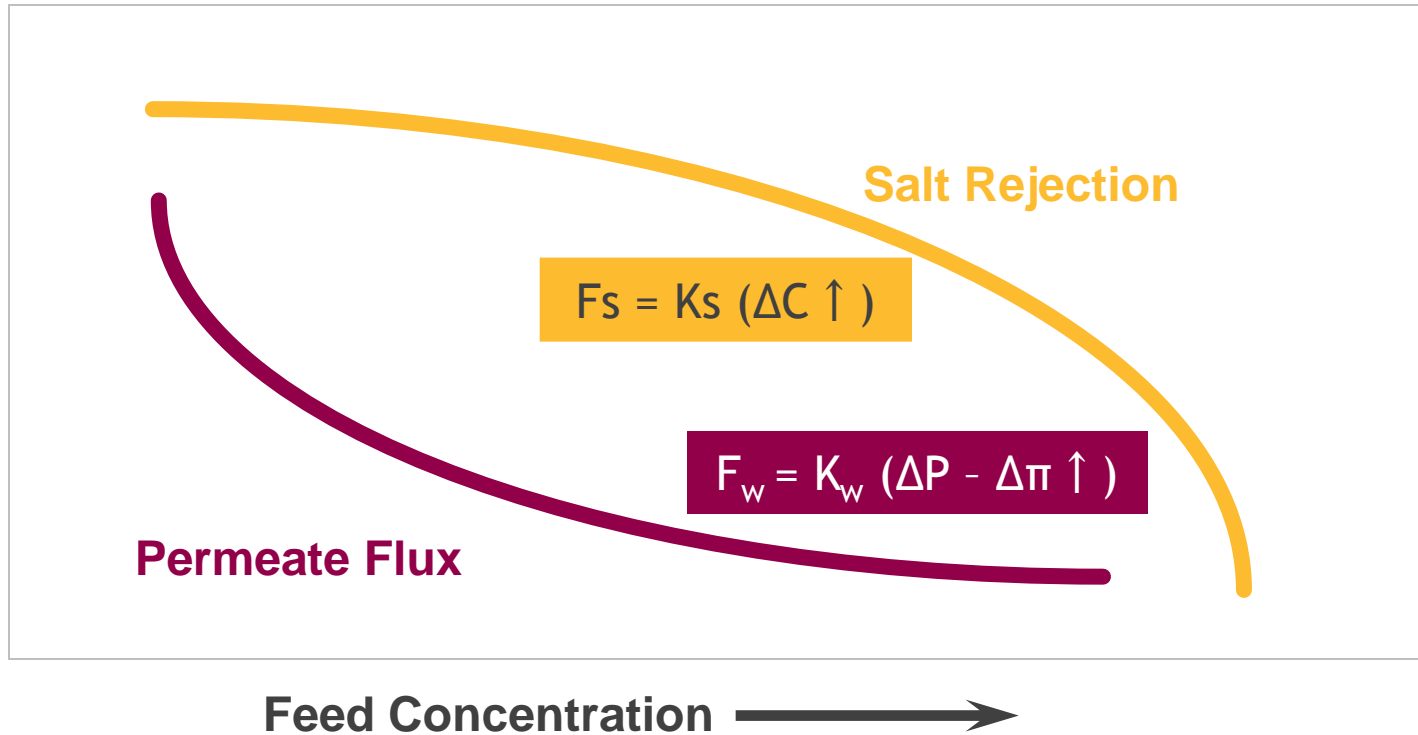
## Permeate flow

- The higher the temperature the higher the permeate flow
- Why? Lower viscosity makes it easier for the water to permeate through the membrane barrier
- RULE OF THUMB – for every 1°C the permeate flow will increase ~ 3%

## Salt passage

- Rule of Thumb: salt passage increases 6% for 1°C increase.
- Increasing temperature increases salt passage more than water passage.
- Generally you will get better rejections at lower temperatures.

# Salt concentration vs. flux and salt rejection



Assuming temperature, feed pressure and recovery are constant

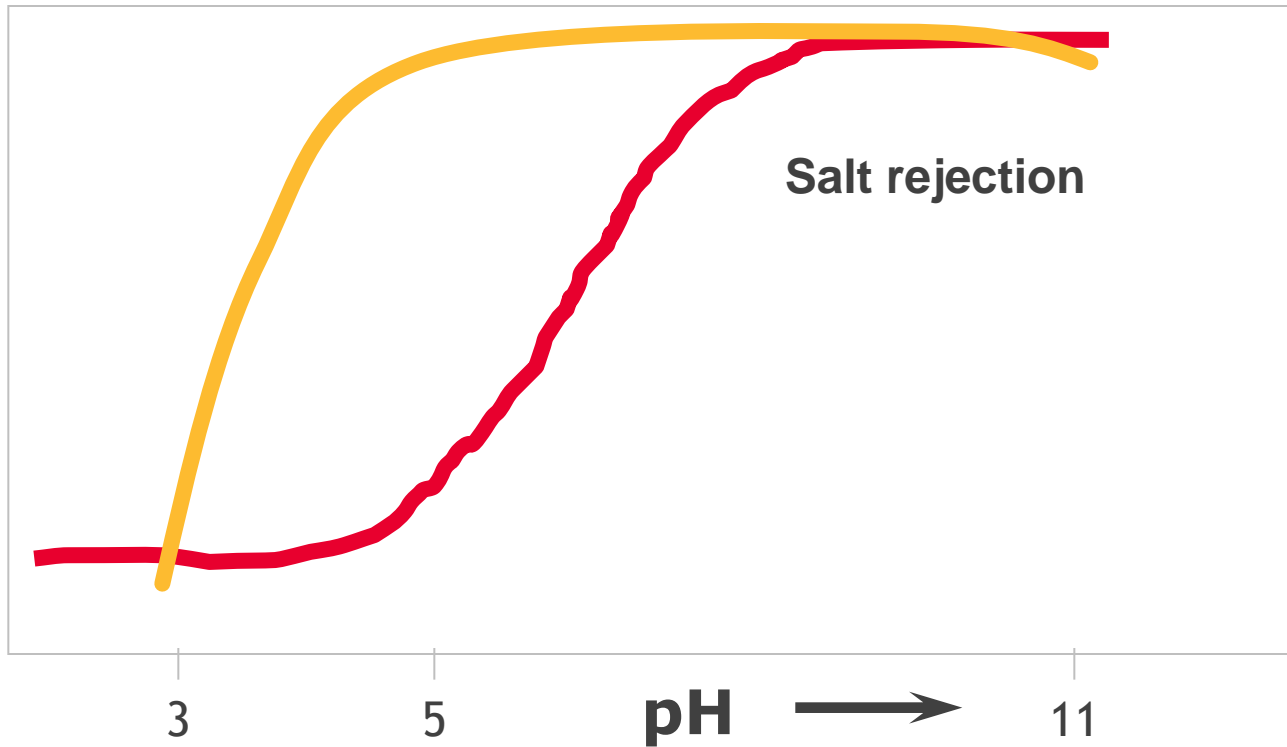


# Salt concentration affect



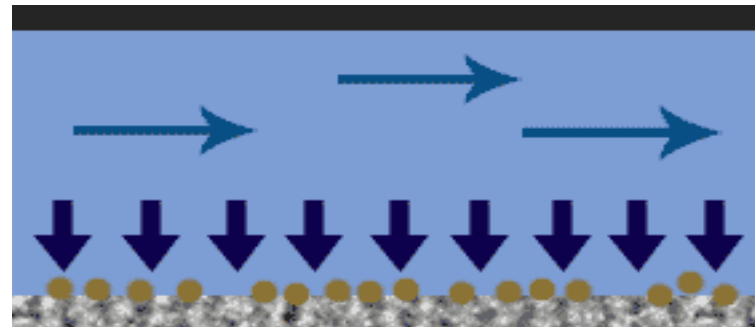
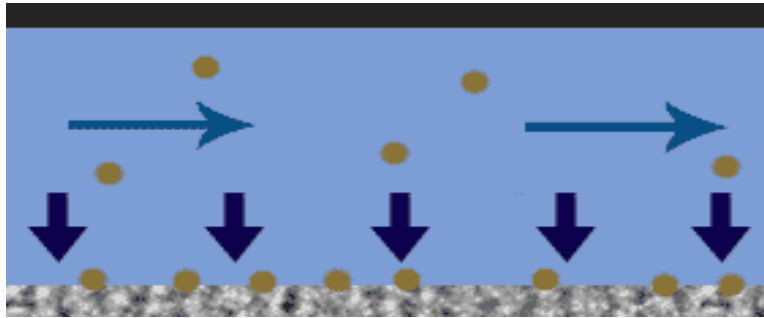
- Salt concentration affect on permeate flow
  - Higher salt concentration will decrease the permeate flow.
  - Why? Because higher osmotic pressure will reduce the NDP.
- Salt concentration affect on salt passage
  - Higher salt concentration will increase the salt concentration gradient and increase the rate of salt passage.
- Salt concentration affect on permeate quality
  - Overall water quality is lower for two reasons, higher rate of salt passage combined with less permeate water.

# pH influence on salt rejection



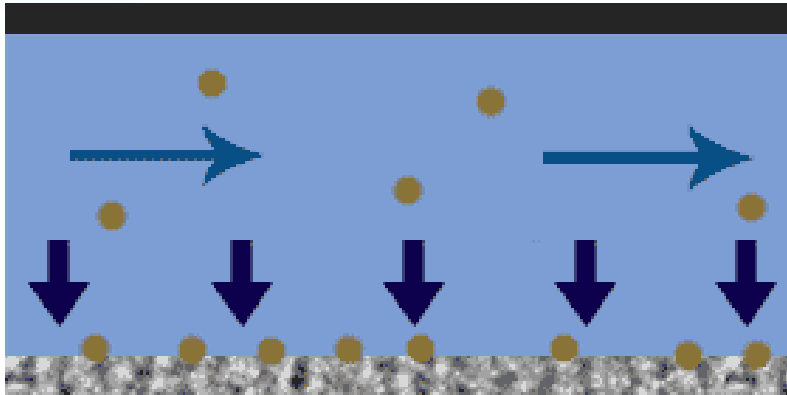
Assuming temperature, feed pressure and concentration are constant

# Boundary layer

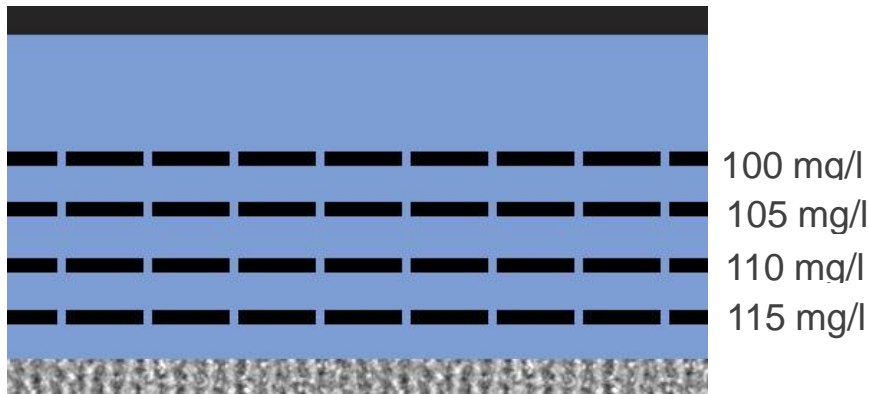


- Water near the membrane surface has little to no cross flow
- Creates an area for particulates & colloids to collect and foul the membrane.
- Water flux through the membrane helps hold foulants in place.

# Concentration polarization



Boundary Layer

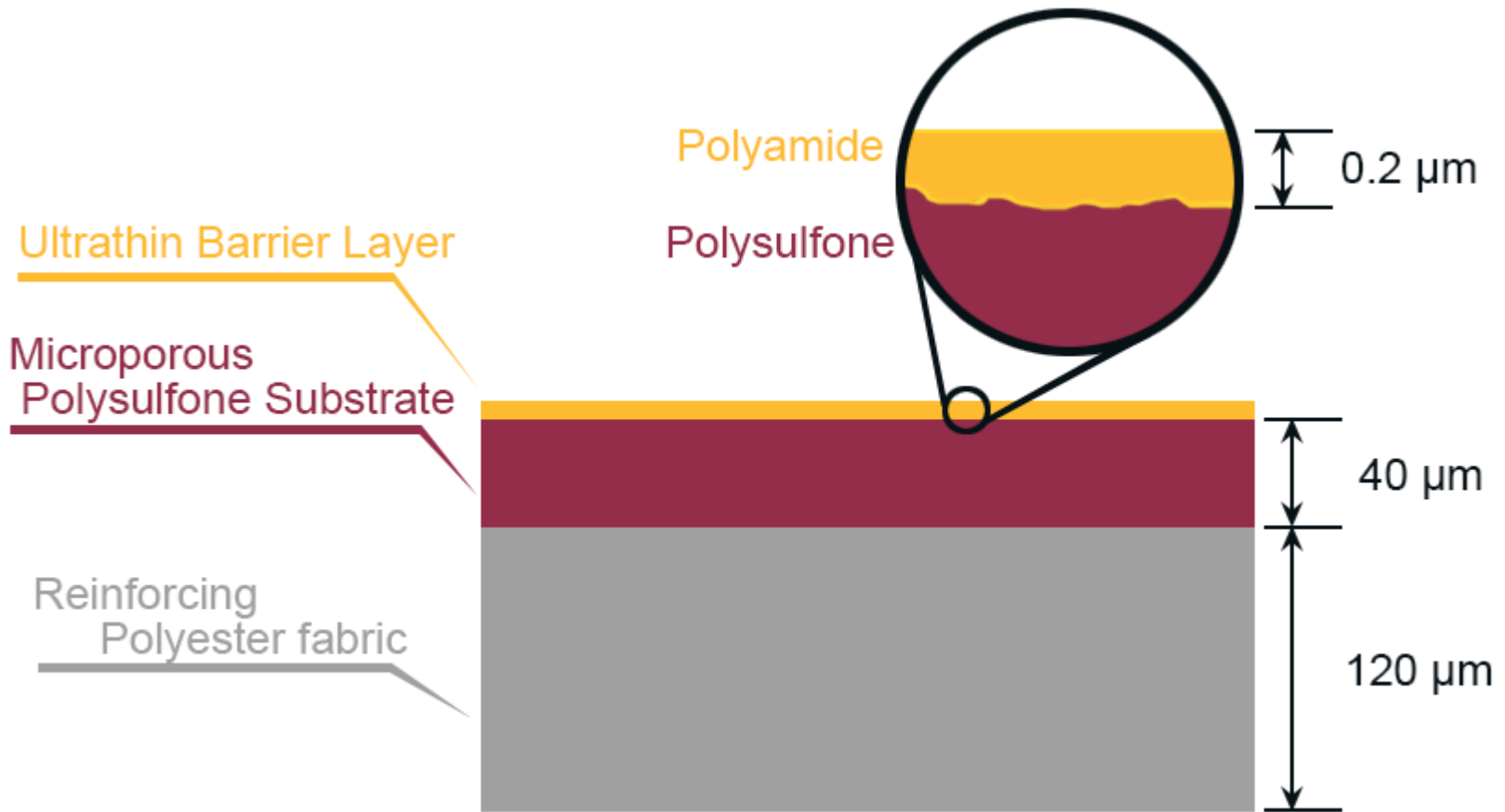


- Concentration polarization is a function of the boundary layer.
- It results in an increased salt concentration at the membrane surface.
- The higher the flux rate through the membrane the higher the salt concentration at the membrane surface.
- Typically the TDS is 13–20% higher than the concentration in the bulk stream.

The background features a blue gradient with a wavy, rippled texture resembling water. A solid dark blue horizontal band runs across the middle of the image, serving as a backdrop for the text.

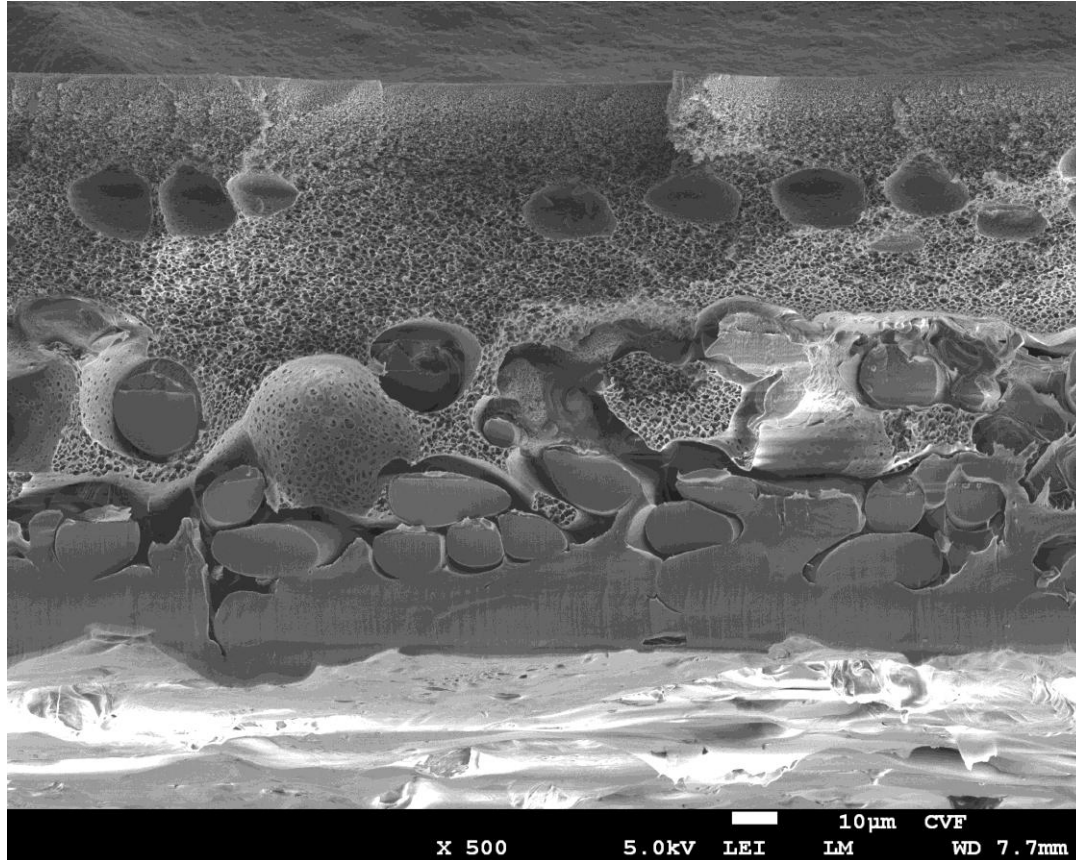
# **Thin Film Composite Membranes Spiral Wound Elements**

# Cross-section of thin film composite membrane

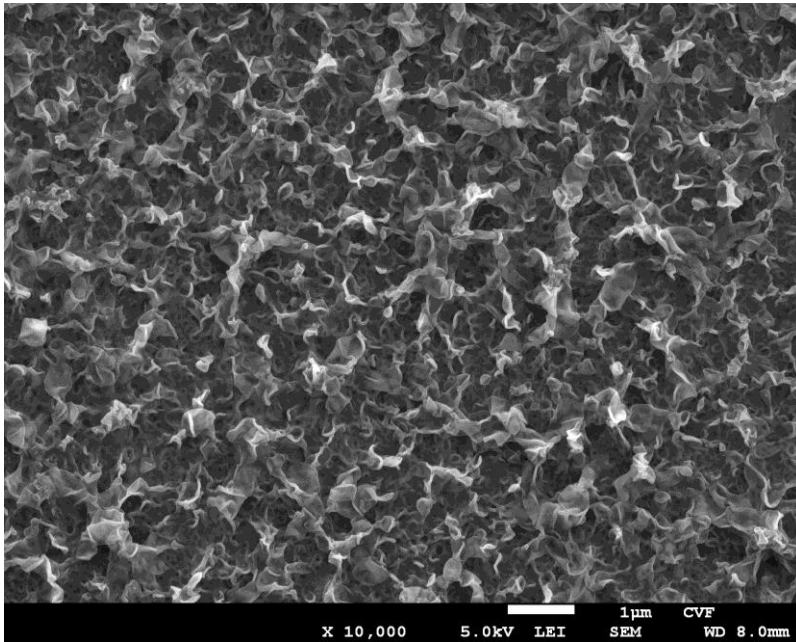




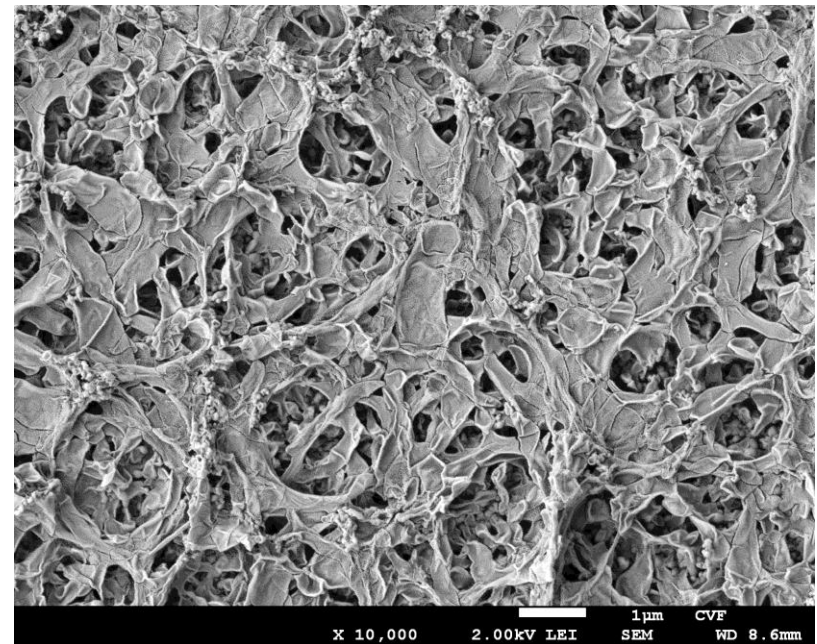
# FILMTEC™ membrane cross-section (SEM image)



# Surface of barrier layer of FT30 (SEM image)

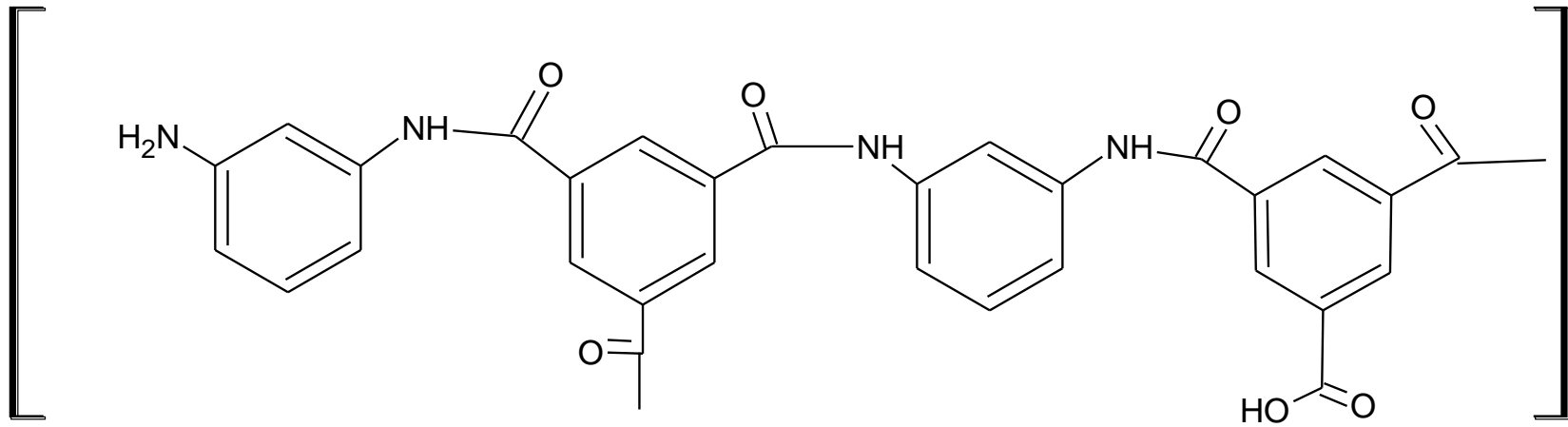


**BW30 Membrane**



**XLE Membrane**

# Flat sheet membrane FT30 chemistry



Free amine

Carboxylate

Aromatic Polyamide Barrier Layer

# Factors affecting membranes solute rejection



## Membrane type/condition:

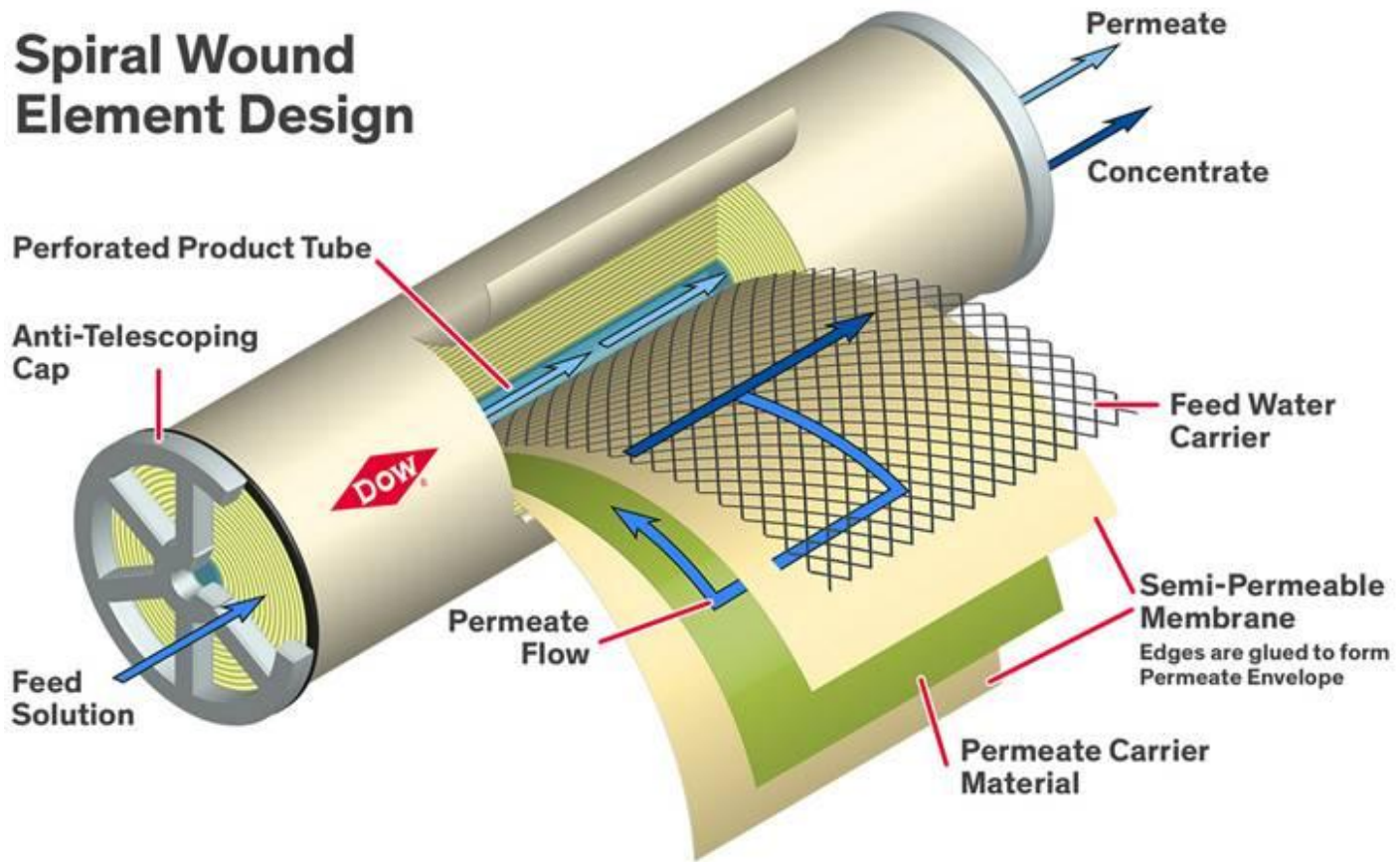
- SW30XHR NaCl 99.75%,
- XFRLE NaCl 99.4%
- NF90: NaCl 85-95%

## Solute characteristics

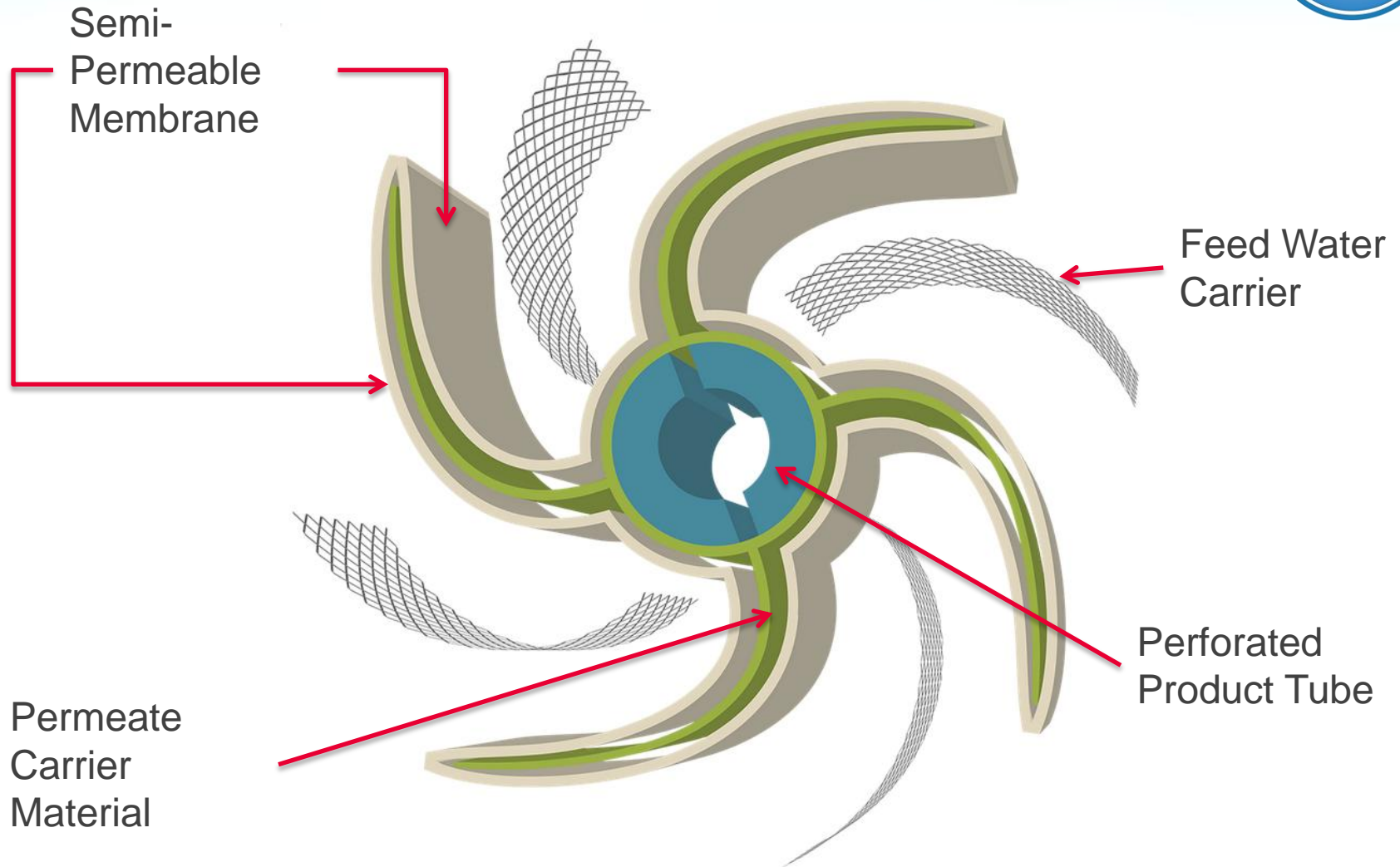
- Charge
- Polarity and/or Degree of Dissociation
- Degree of Hydration
- Molecular weight and Degree of Branching



# Spiral wound RO membrane element



# Spiral wound RO membrane element



# FILMTEC™ product range



## Brackish Water

- High rejection
- Low energy
- Fouling resistant

## Seawater Desalination

- Low energy
- High rejection

## Nanofiltration

## Special products

- Ultrapure Water
- Sanitary style
- Food and Dairy

## Flexible sizing

- 8" X 40"
- 4" X 40"
- 2.5" x 40"
- 1.8" x 12"

## Delivery

- Dry
- Wet



# Applications and markets



## Municipal

- Sea Water desalination & brackish water purification for potable use
- Agricultural irrigation

## Industrial

- UPW, process water, boiler feed water and utility water
- Water purification or concentration of substances

## Water reuse

## Commercial

- Car Wash, Laboratory, Restaurant

## Food and Nutrition

- Dairy, Juice, Beverages

## Military

## Households





**Thank You!**

For more information please visit our web site or  
contact your local Dow representative.

<http://www.dowwaterandprocess.com/>

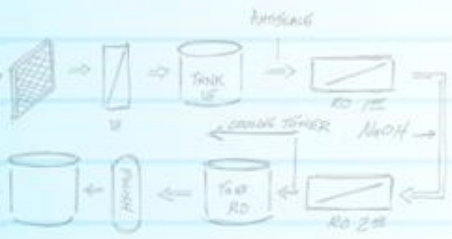
**Questions?**



*Expected Conductivity Levels?*

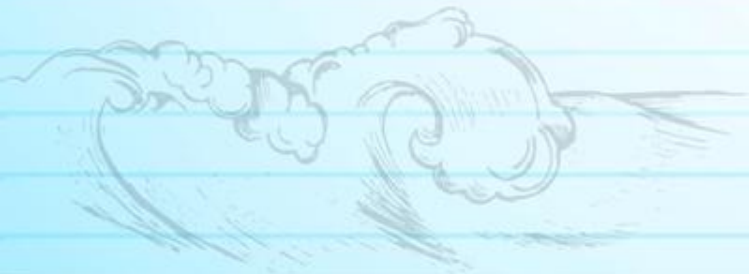
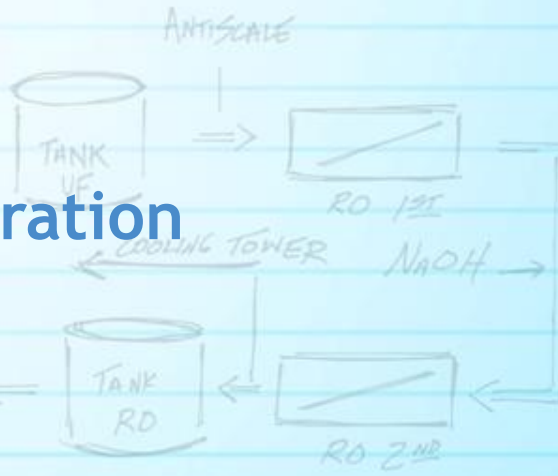


*Deaerating  
pH Break vs. Con  
Break - Cycle*



*What are the  
Water Quality  
Guidelines?*

# Reverse Osmosis System Operation



Scott Beardsley



# Content



- Operation of membrane plants
- Operational steps
  - Loading
  - Start-up
  - Shut-down
  - Performance monitoring
    - Recordkeeping for RO Systems
    - Factors Influencing RO Performance
    - Data Normalization

# Operation of membrane plants



- Successful long term performance depends on proper operation and maintenance of the system
- Proper operation is required to control fouling and scaling

# Operation of membrane plants



1. Element Loading
2. Start-Up
3. Shut-Down
4. Performance Monitoring



A close-up photograph of several brass valves or handles, likely from a steam engine or industrial machinery. The valves are arranged in a row, with the one in the foreground being the most prominent and in sharp focus. Each valve has a circular, spoked design. A semi-transparent blue horizontal band is overlaid across the middle of the image, containing the text "Element Loading" in white. The background is dark and out of focus, emphasizing the metallic texture and form of the valves.

# Element Loading

# Element loading

## -Standard 8” membrane elements



1. Cleaning of pressure vessels (PVs) with water and lubrication with glycerin
2. Closing of PV's brine end
3. Preparation of elements
4. Loading of elements
5. Shimming
6. Closing of PV's feed end



# Cleaning and Lubrication of PVs



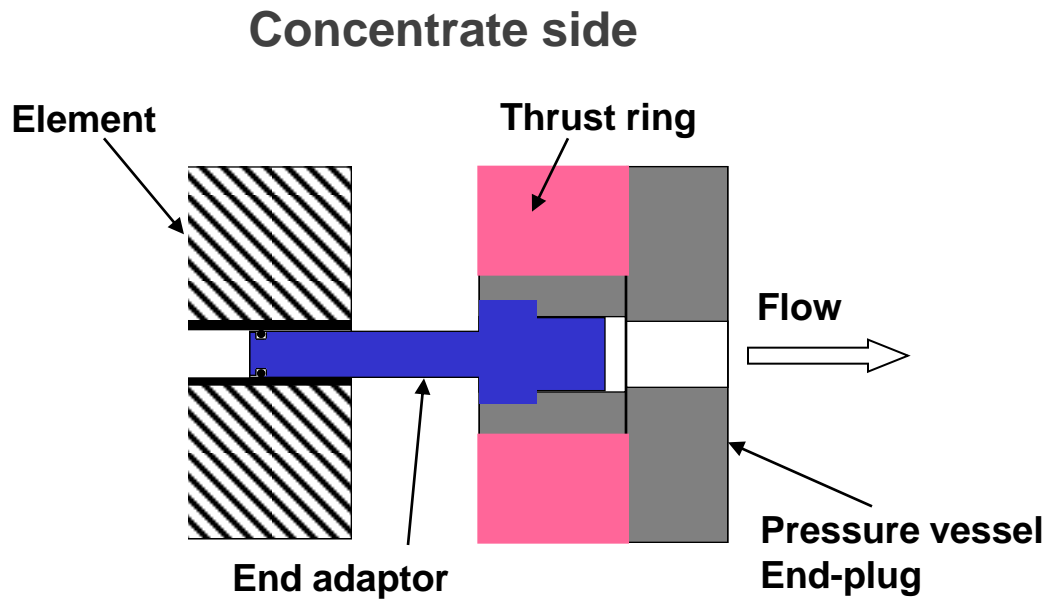
1. **Flushing** PVs with a pressurized water hose
2. **Cleaning** with sponge & water
3. **Lubrication** with sponge and glycerin/water (50/50)



# Closing brine end



1. Insert thrust ring in empty PV
2. Close with lubricated end connector and end cap before loading



## Example for thrust ring



Alternative: Close brine end with thrust ring but without end connector temporarily for loading of each PV. This is to avoid damage to the end connector when moving the element into the fixed end connector.

# Preparation of elements



- **Unpack** elements and place on clean surface (e.g. horizontally on a table, or vertically on clean floor –cardboard layer)
- **Check** appearance of elements, esp. the inside of the permeate water tube (PWT) and correct direction of the brine seal
- **Note** Serial numbers for loading plan
- **Lubricate** (1) interconnectors (O-rings) and the inside of the PWT's with very little amount of Silicon grease\*; (2) brine seals to facilitate the posterior element removal



\* Dow Corning® 111; Molykote® 111

WATER & PROCESS SOLUTIONS



# Loading

## -1<sup>st</sup> element and interconnector



- Place first element (last position, e.g. #7) into PV
- Place lubricated interconnectors into Feed end of PWT  
Turn and push interconnector at the same time!



Silicon lubricant: **Dow Corning® 111** or **Molykote® 111**

Other lubricants may cause performance issues!



# Brine seal check and lubrication

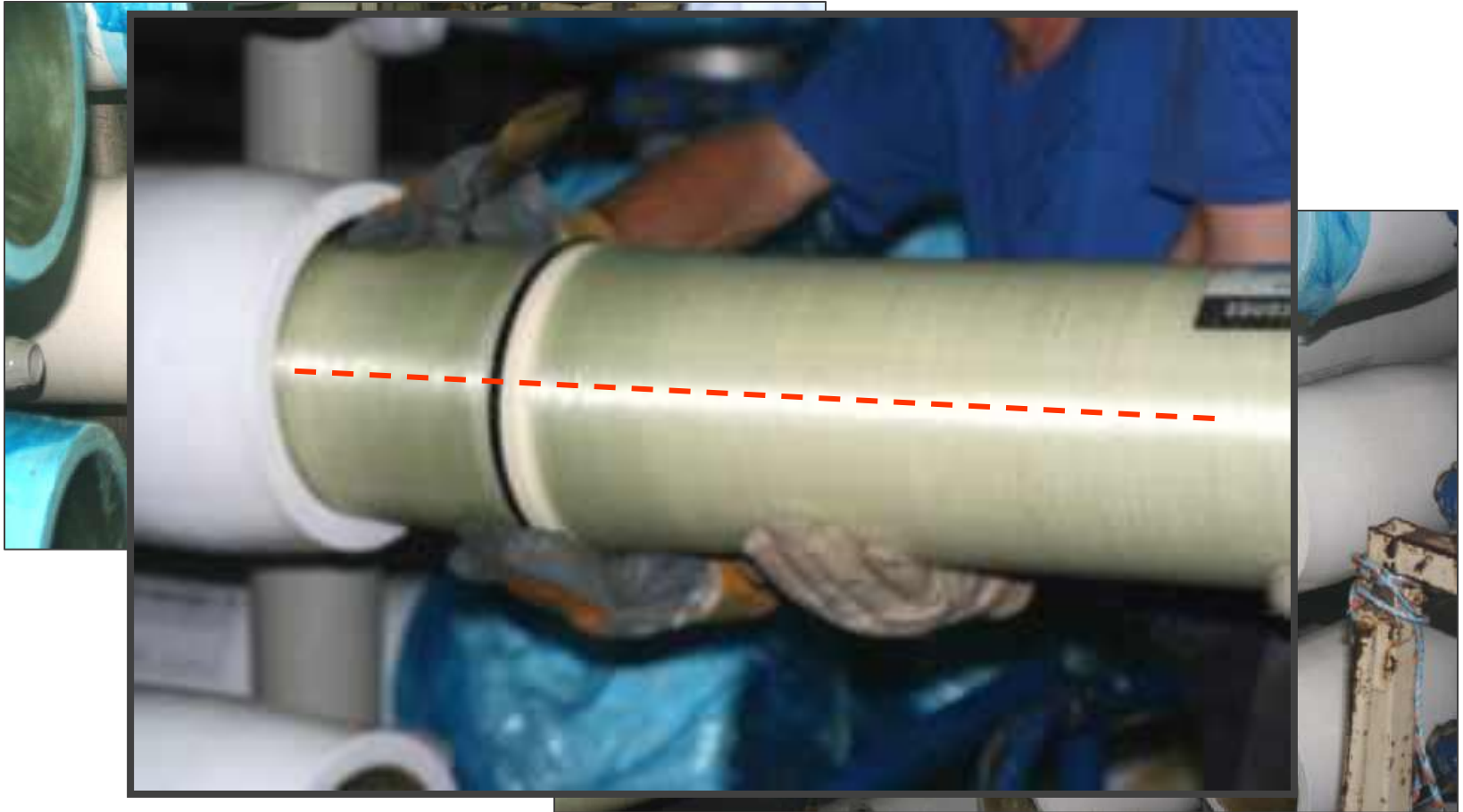


- glycerin/water (50/50) solution
- food grade glycerin
- Dow Corning® 111

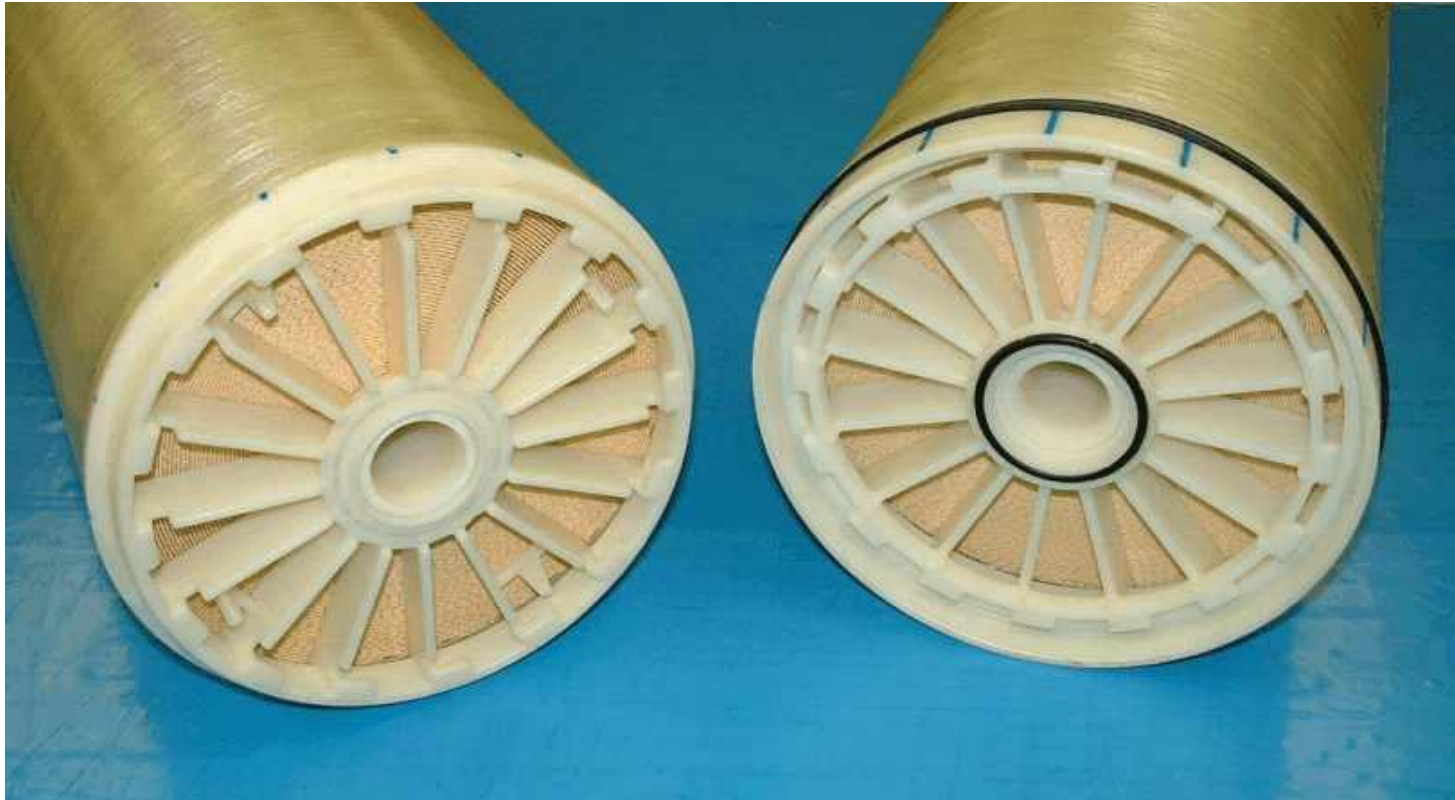
# Adding elements



**Always support the element to keep it horizontal!**



# iLEC™ Elements



See Training video on

<http://www.dowwaterandprocess.com/en/resources/>

Keyword “iLEC”

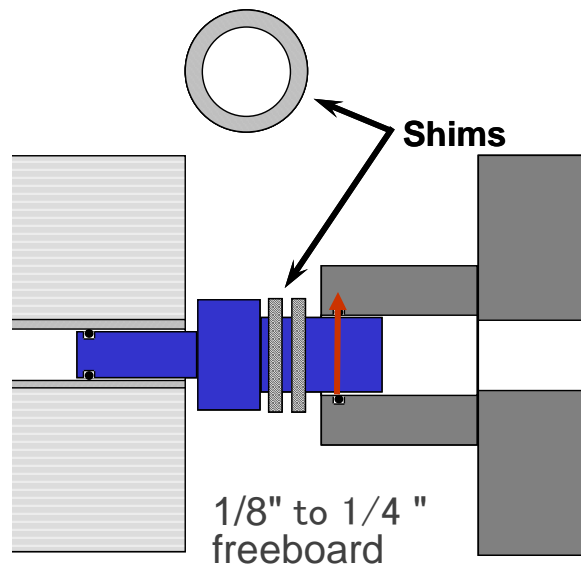




# Shimming



Feed end



1. Push elements with appropriate tool
2. Shim so that the endconnector cannot move when PV is closed





# Closing of PV's Feed End



1. Place segmented ring
2. Close with spring



A close-up photograph of several brass valve wheels (handwheels) mounted on a pipe. The wheels are arranged in a row, receding into the background. The lighting is dramatic, highlighting the metallic texture and the circular shape of the wheels. A solid blue horizontal band is superimposed across the middle of the image, serving as a background for the text.

# **Start Up Checklist & Sequence**

# Checklist for start-up (1/2)



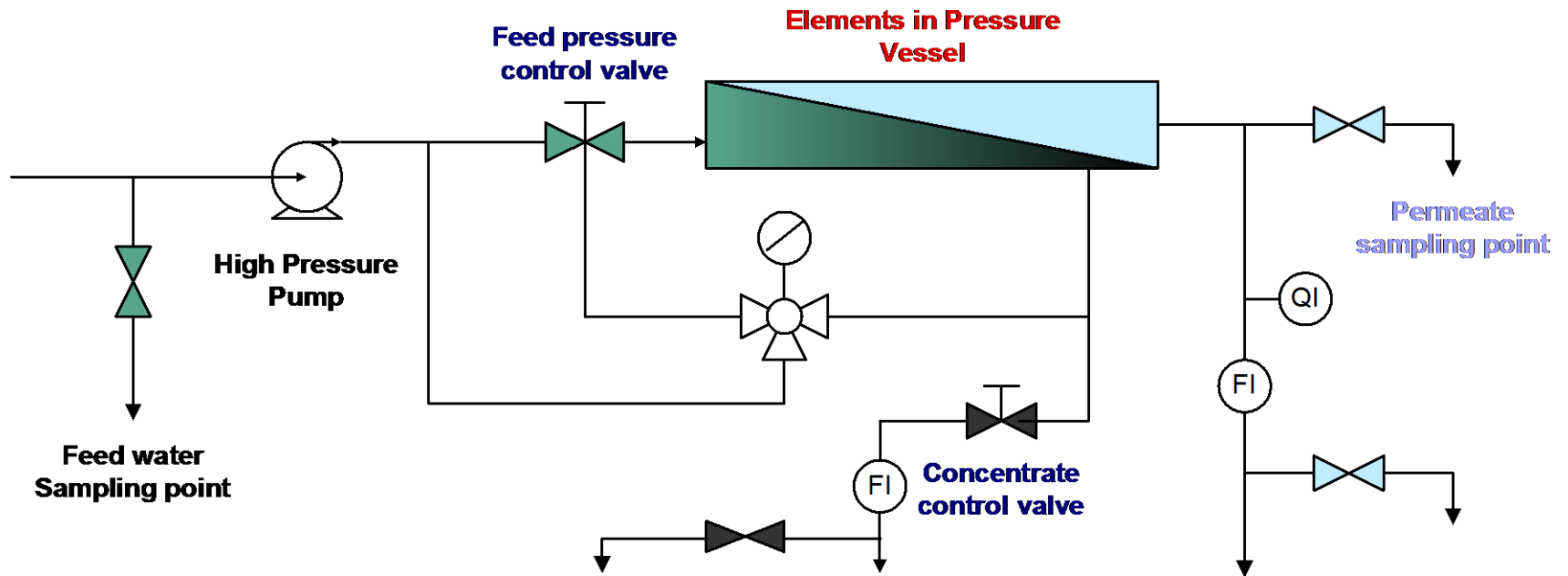
- ✓ Pretreatment
- ✓ Membrane units
- ✓ Turbidity and SDI
- ✓ Alarm shut downs (redox/pH, no sodium bisulfite, no acid, no antiscalant, temperature, pressure)
- ✓ Instrumentation is appropriate, properly installed and calibrated
- ✓ Provisions to prevent product back pressure (< 5 psi)

# Checklist for start-up (2/2)



- ✓ Sampling valves installed
- ✓ Pressure vessels secured and piped for operation
- ✓ Pumps and valves ready for operation (permeate open to drain, reject flow control valve open, feed flow valve throttled and/or pump bypass valve partly open – feed flow < 50% of normal)
- ✓ Monitoring equipment
- ✓ Water analysis equipment

# RO system start-up



# Start-up sequence



1. Rinse upstream section to flush out contaminants
2. Check correct setting of all valves
3. Purge air out of system at low pressure
4. Check for leaks
5. Partially close feed pressure control valve
6. Start high pressure pump
7. Slowly open feed control valve
8. Slowly close brine control valve to adjust to design recovery
9. Adjust to design product flow with feed and brine valves
10. Check all chemical dosages rates and brine LSI
11. Let system stabilize one hour
12. Record all operating parameters
13. Check permeate conductivity from each vessel
14. Take water samples and analyze
15. Compare performance to prediction
16. Lock plant in automatic operation
17. Record operating data frequently over first 48 hours. This provides a baseline for all future readings





**Shut-down**

# Reasons for Shut-down



- Storage tank full; operation not required
- Start-up not successful
- Power outage
- Scheduled maintenance
- Cleaning
- Number of shut-downs should be kept at a minimum

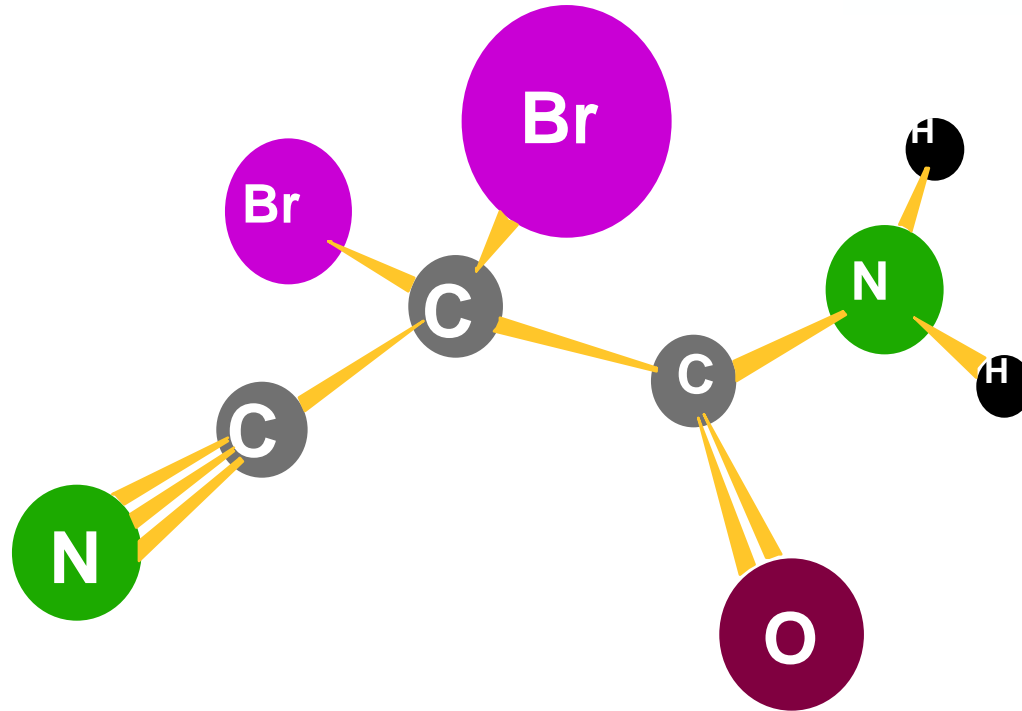


# Shut-Down Considerations



- Automatic flush at low pressure (~ 45-60 psi) for about 3 minutes ( $C_f=C_b$ )
- Flush water quality
  - Permeate water preferred
  - No pretreatment chemicals (except sodium bisulfite)
  - No free chlorine
  - DBNPA may be added

# 2,2 Di Bromo-3-Nitrilo Propion Amide



## Features:

- Quick kill
- Rapid degradation
- Low use concentrations
- Non-oxidizing

# Precautions during Shut-Down Period



- After flushing keep system full of water with no air (this becomes extremely critical when  $H_2S$  is present)
- Keep system cool but frost-free
- Avoid temperatures  $> 35^{\circ} C$
- Protect membranes from microbiological growth
  - Flush at least once every day with permeate or good quality feed water
  - Operate the system for a short time once every day
  - Preserve the system



**Preservation**

# Preservation



Required for periods > 48 hours without flushing or operation

- Preservation solution: 1 - 1.5% sodium bisulfite
- Renew solution if pH drops below 3 or latest after one month
- Keep system cool but frost-free
- Avoid temperatures > 35° C



# Performance monitoring

# Performance monitoring



1. Recordkeeping for RO Systems
2. Factors Influencing RO Performance
3. Data Normalization

# Performance Monitoring

## -Why?



- To track performance of system trends
- To decide when to clean
- To decide when to replace membranes
- Useful information in troubleshooting
- Required in event of warranty claim



# Performance monitoring

## -How?



- Record operating data on log sheet
- Normalize data to account for feedwater pressure, temperature, concentration and recovery
- Graph salt passage, product flow and DP vs. time

# Recordkeeping for RO Systems



- Recommendations for RO operating records are in ASTM D 4472
- Data which should be recorded is:
  - Permeate and concentrate flows
  - Feed, concentrate and permeate pressures
  - Feed temperature
  - Feed pH
  - Feed, concentrate and permeate concentrations

# Data normalization

## -Why normalize?



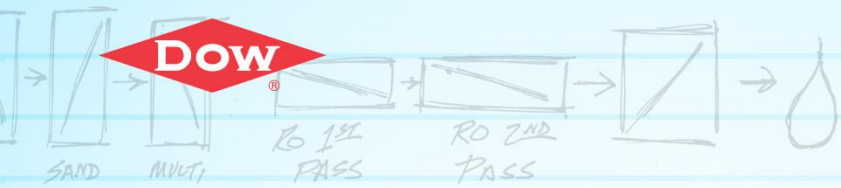
Fluctuations in operating conditions cause permeate flow and salt passage to change. Performance changes due to membrane properties might go undetected.

Normalization eliminates the effects of fluctuating operating conditions and allows monitoring of the membrane properties.

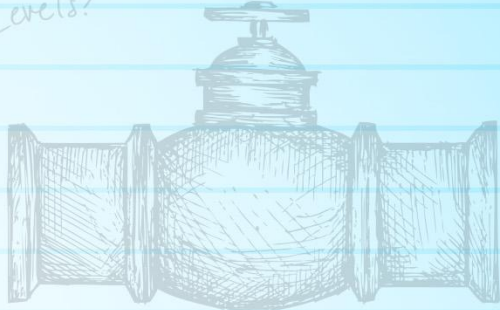
**Thank You!**

For more information please visit our web site or  
contact your local Dow representative.

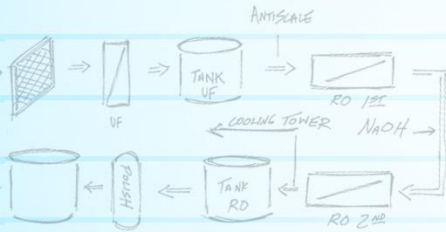
<http://www.dowwaterandprocess.com/>



*Expected Conductivity Levels?*

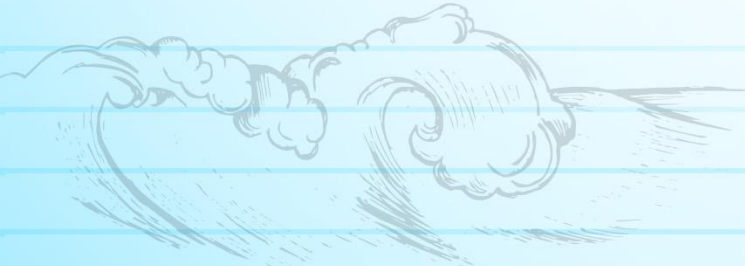
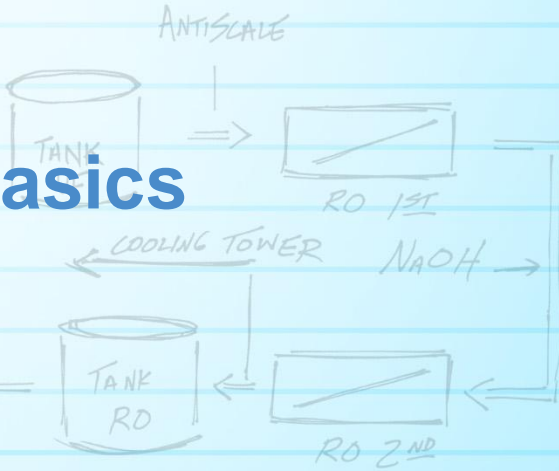


*pH Break vs. Con Break - Cycle*



*What are the standard Water Quality Guidelines?*

# Reverse Osmosis Design Basics



Scott Beardsley



# RO System Design Webinar Series



## Reverse Osmosis System Design Basics

**Date & Time**  
Sept 9, 2015  
1-3 pm CDT

### RO Webinar Series Speakers:



Scott Beardsley & Steven Coker  
Technical Service Specialists

## Advanced Reverse Osmosis System Design

**Date & Time**  
Sept 23, 2015  
1-3 pm CDT

## ROSA System Design Basics

**Date & Time**  
Sept 11, 2015  
1-3 pm CDT

## Advanced RO System Design with ROSA

**Date & Time**  
Sept 30, 2015  
1-3 pm CDT

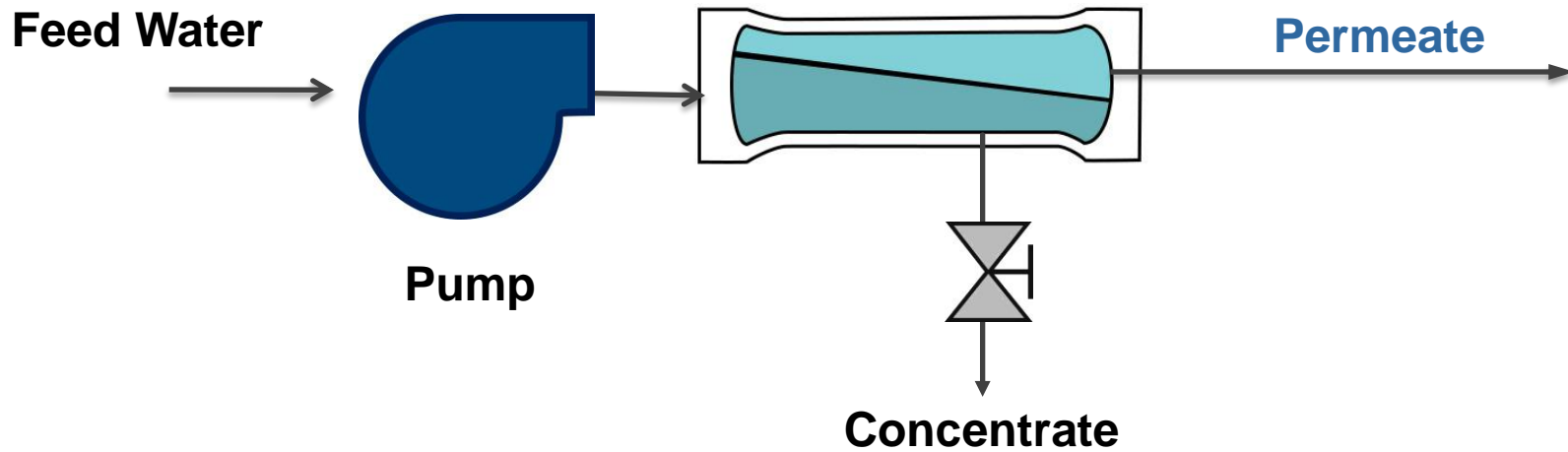
# Overview



1. Scope of system design
2. System configuration types
3. System design guidelines
4. Ten steps to design a membrane system

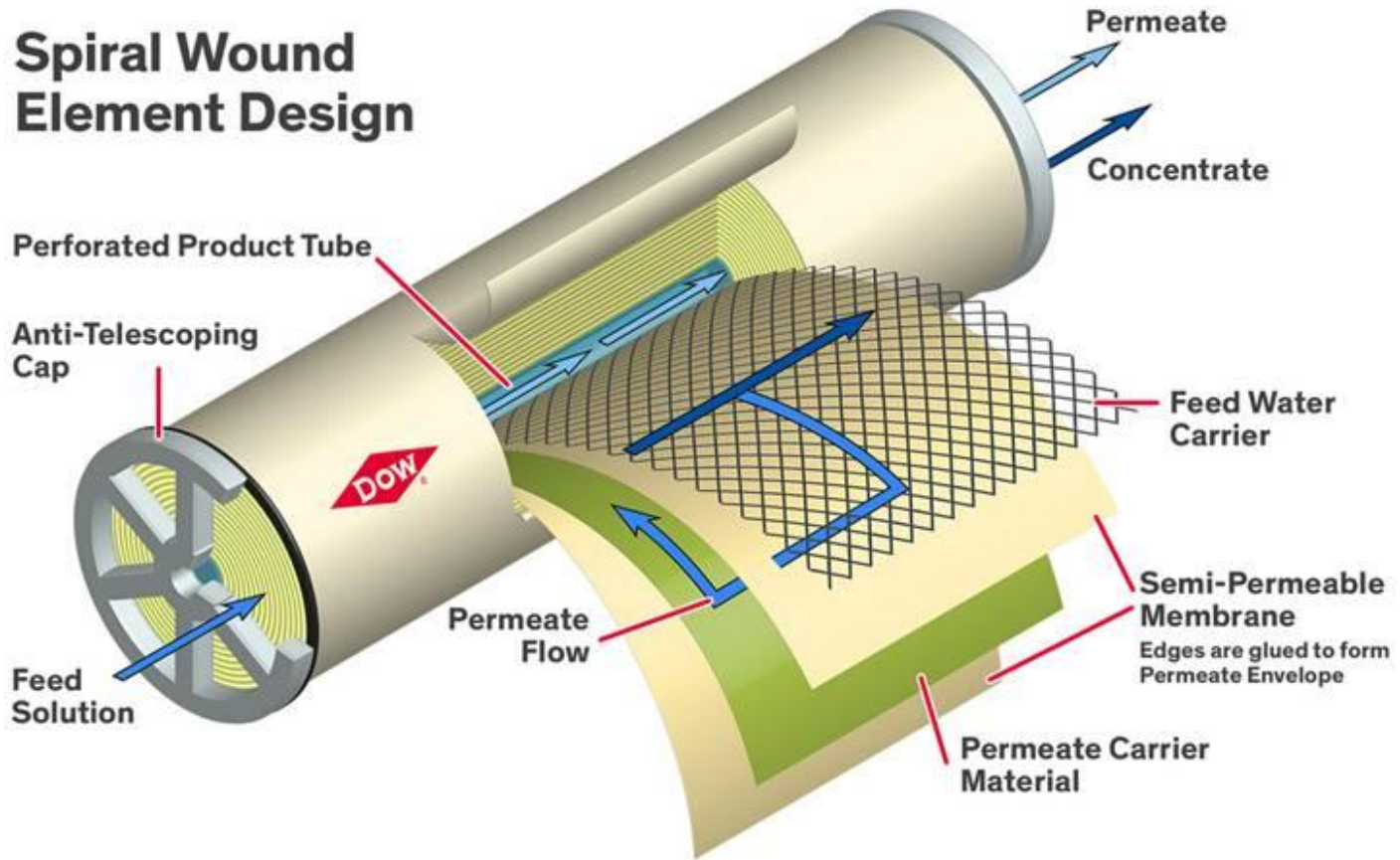


# Simplified RO system



100 to 600 psi (7 to 42 bar) -brackish water  
800 to 1,200 psi (55 to 83 bar) -seawater

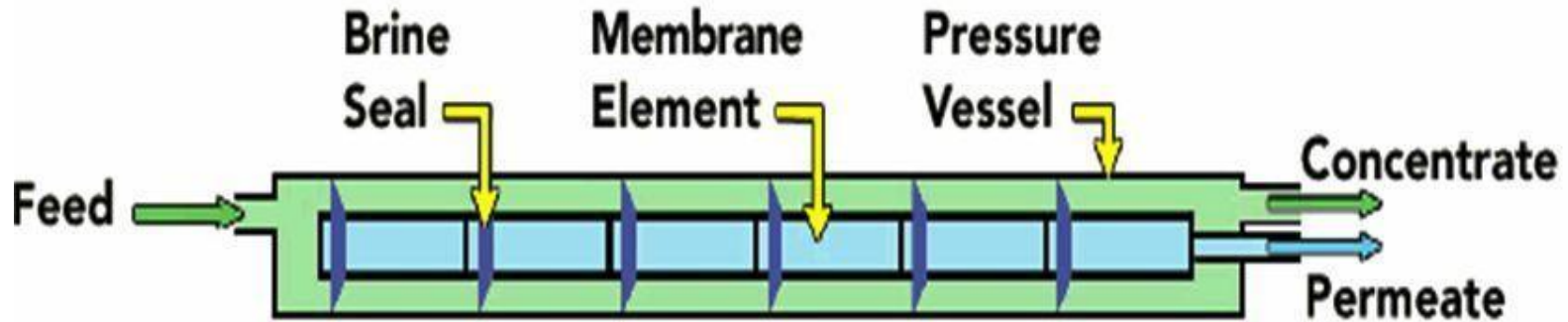
# Spiral wound RO membrane element



# Main components of a membrane system



Serial arrangement of membrane elements in a pressure vessel



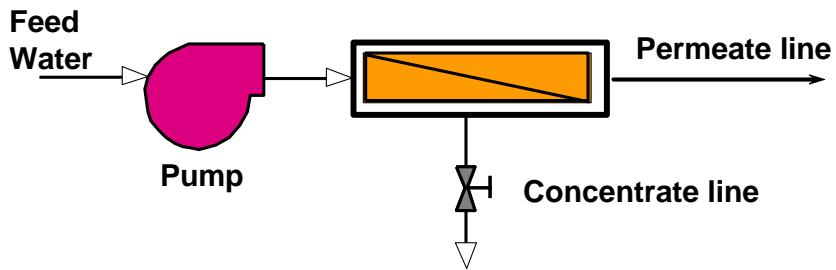
DOW FILMTEC™  
RO Element



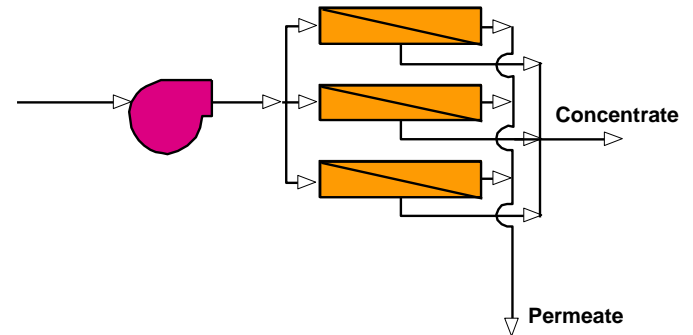
# System configuration types



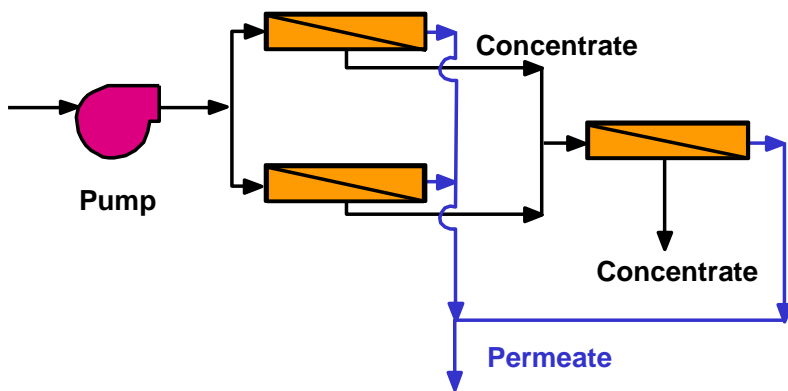
### Single Vessel



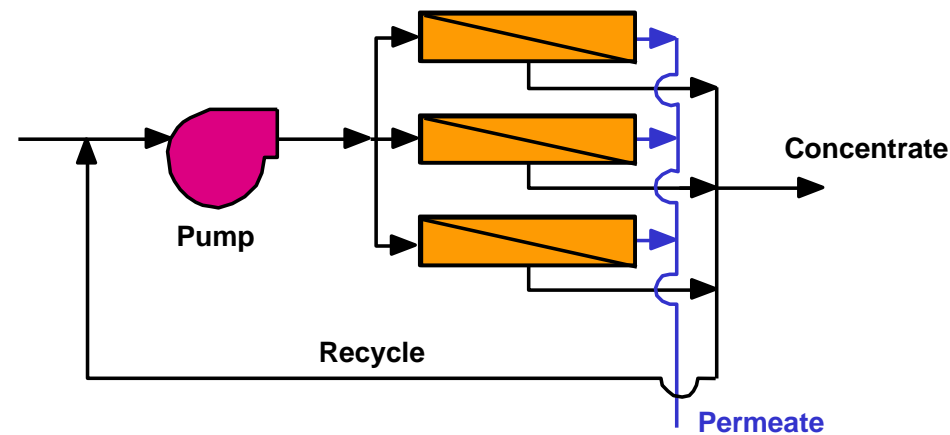
### Single Stage



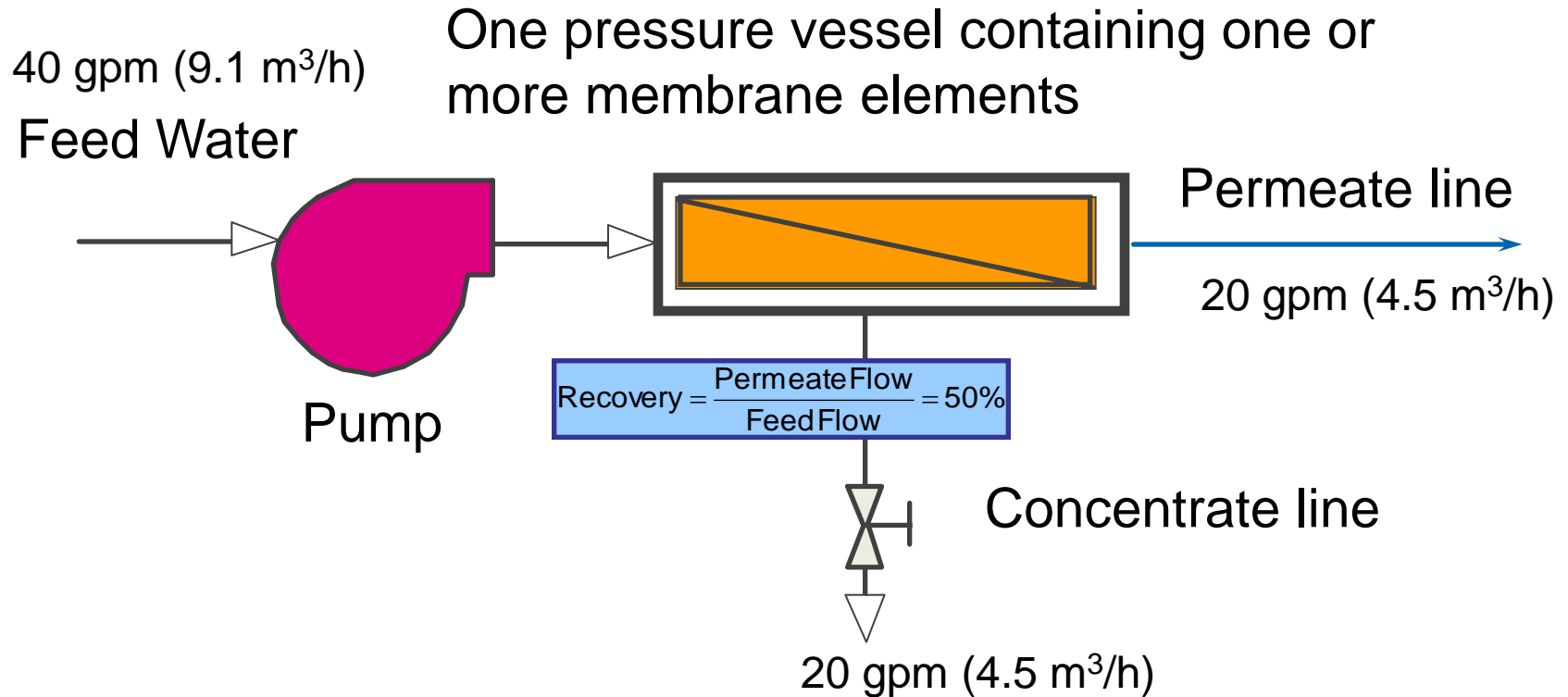
### Multistage



### Concentrate Recycle



# Configuration- single vessel system

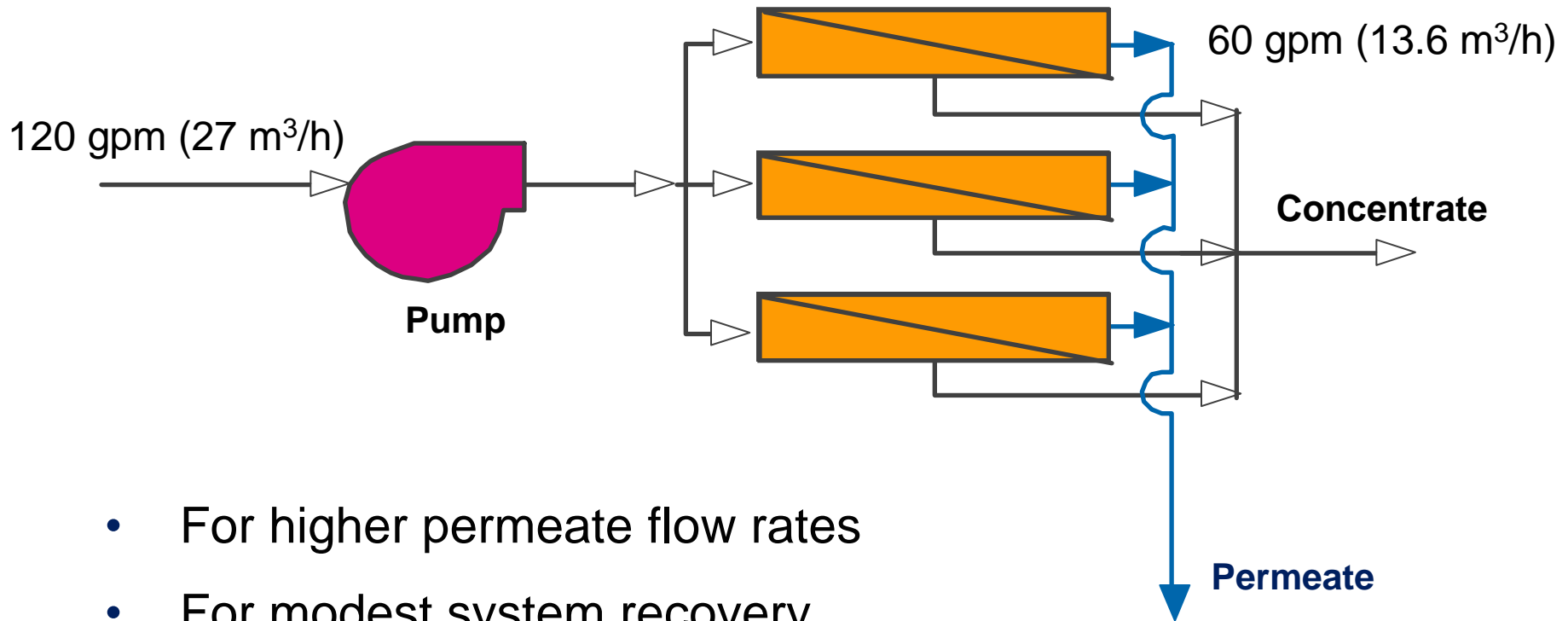


- For low flow rate
- For low system recovery

# Configuration- single stage system



Pressure vessels in parallel with common feed, concentrate and permeate connections



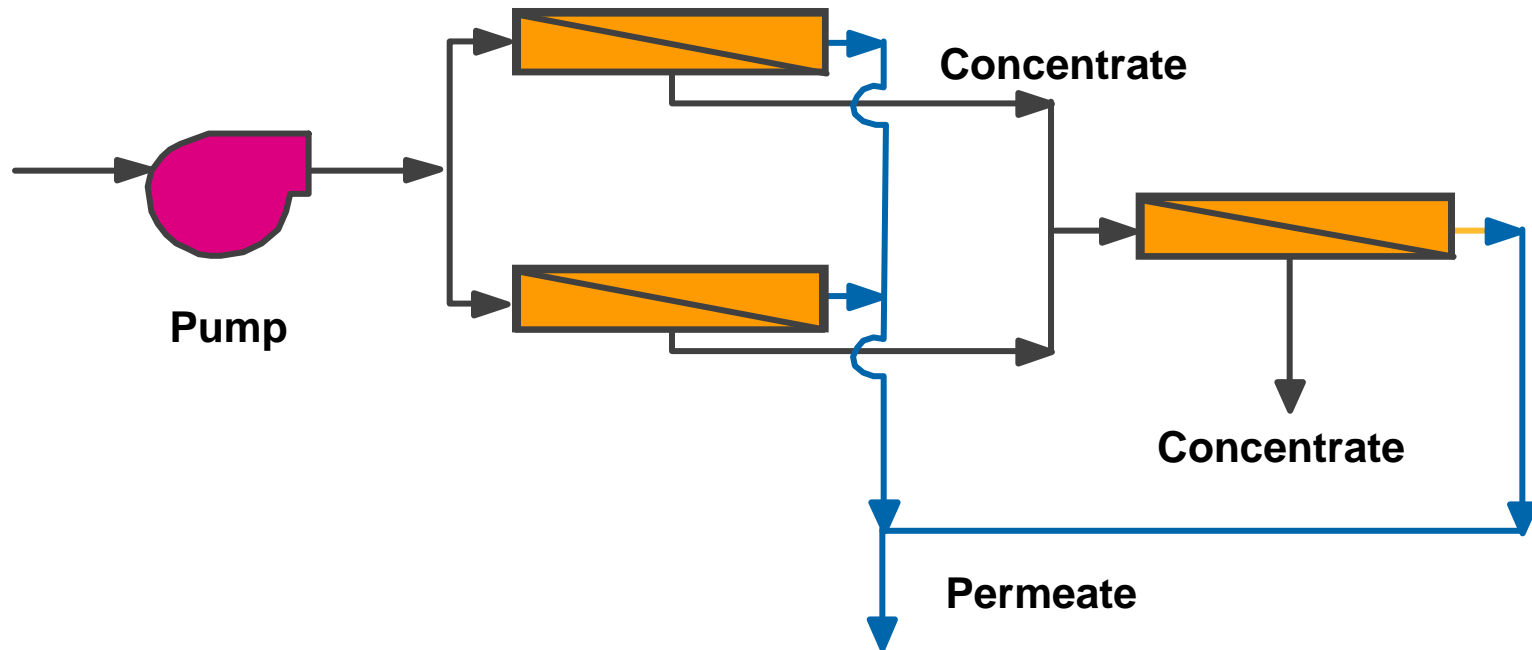
- For higher permeate flow rates
- For modest system recovery
- Typical in seawater desalination

$$\text{Recovery} = \frac{\text{PermeateFlow}}{\text{FeedFlow}} = 50\%$$

# Configuration- multi-stage system



## Two-stage system



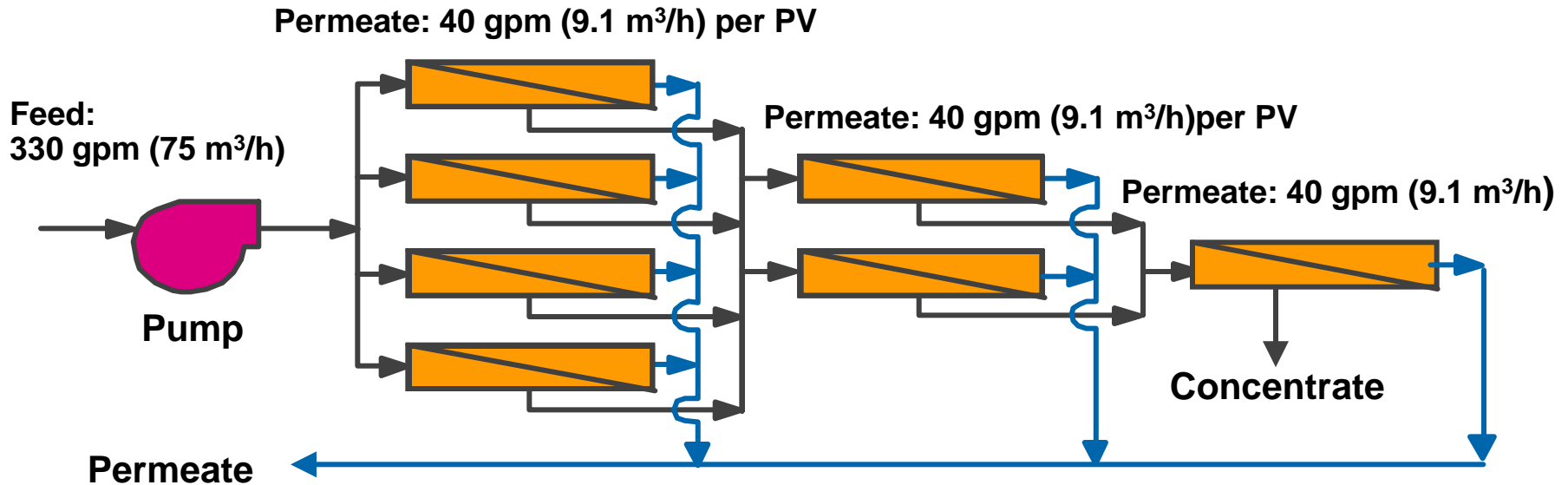
- Use for higher recovery
- Typical 75% recovery with 6-element vessels



# Configuration- multi-stage system



## Three-stage system



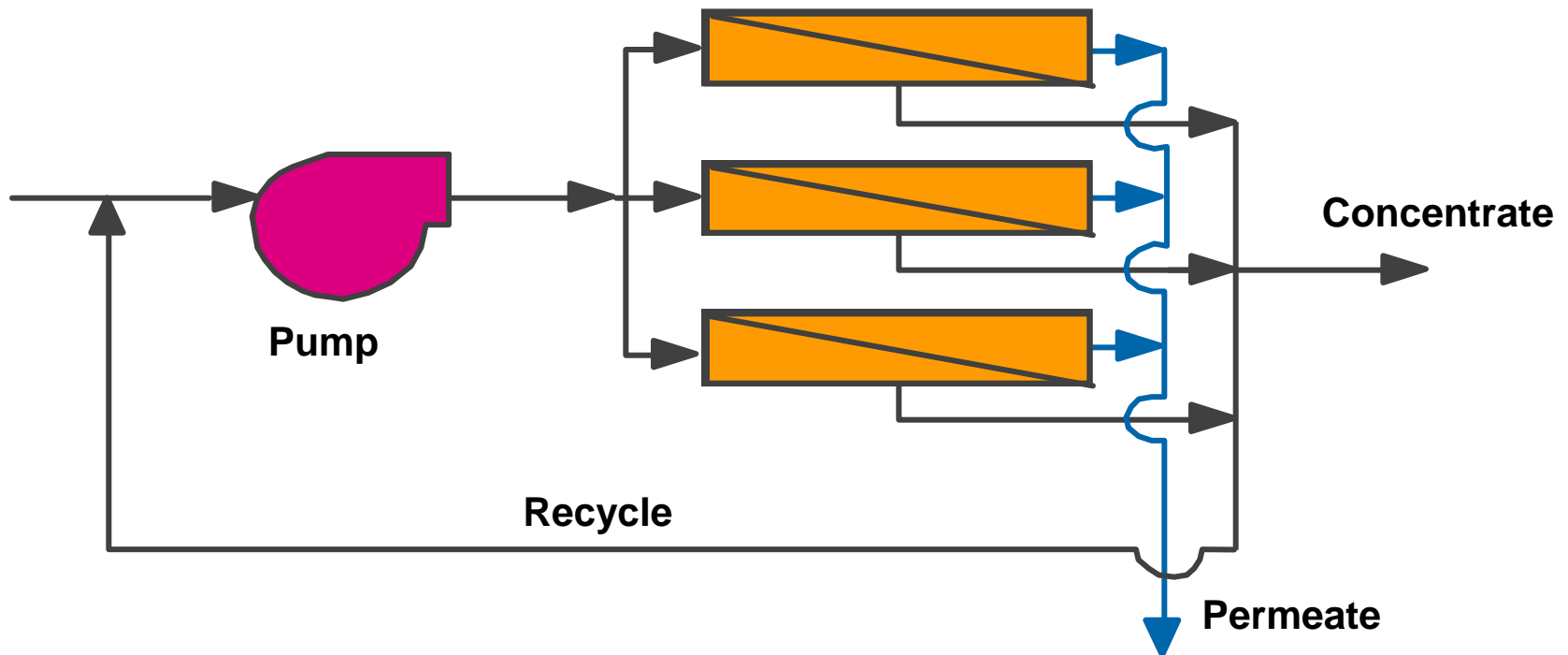
$$\text{Recovery} = \frac{\text{Permeate Flow}}{\text{Feed Flow}} = \frac{160 + 80 + 40}{330} > 85\%$$

- Use for higher recovery
- Typical 85% recovery with 6-elements vessels
- Up to 90% depending on the feed water quality

# Configuration – concentrate recycle



- Way to increase recovery by re-circulating reject to increase feed flow
- Typical for special / waste water applications
- Typical for single vessel systems



# System design guidelines



## Design guidelines for 8-inch FILMTEC elements

	RO permeate	Well Water	Surface Water			Wastewater			Seawater		
			Dow UF	UF/MF <sup>1</sup>	Conventional	Dow UF	UF/MF <sup>1</sup>	Conventional	Dow UF	UF/MF <sup>1</sup> or Well	Open Intake
SDI	<1	<3	<2.5	<3	<5	<2.5	<3	<5	<2.5	<3	<5
Average flux (gfd)	21-25	16-20	16-20	13-17	12-16	11-15	10-14	8-12	9-11	8-10	7-10
Average flux (L/m <sup>2</sup> h)	36-43	27-34	27-34	22-29	20-27	18-26	17-24	14-20	15-18	13-20	11-17
Maximum element recovery (%)	30	19	19	17	15	14	13	12	15	14	13

<sup>1</sup> UF/MF: Generic Ultra/Microfiltration - continuous filtration process using a membrane with pore size of <0.5 micron.

The limiting values listed above have been incorporated into the ROSA software. Designs of systems in excess of the guidelines results in a warning on the ROSA printout.

# System design guidelines



## Design guidelines for 8-inch FILMTEC elements Maximum permeate flow rate per element

	RO permeate	Well Water	Surface Water			Wastewater			Seawater		
			Dow UF	UF/MF <sup>1</sup>	Conventional	Dow UF	UF/MF <sup>1</sup>	Conventional	Dow UF	UF/MF <sup>1</sup> or Well	Open Intake
<b>SDI</b>	<1	<3	<2.5	<3	<5	<2.5	<3	<5	<2.5	<3	<5
<b>Active Membrane Area (ft<sup>2</sup>)</b>	Maximum permeate flow rate, gpd (m <sup>3</sup> /d)										
<b>365</b>	10.200 (38)	8.500 (32)	8.500 (32)	7.200 (27)	6.600 (25)	6.300 (24)	5.900 (22)	5.200 (20)	X	X	X
<b>380</b>	10.700 (40)	8.900 (34)	8.900 (34)	7.500 (28)	6.900 (26)	6.500 (25)	6.000 (23)	5.200 (20)	7.900 (30)	7.600 (29)	7.200 (27)
<b>400</b>	11.200 (42)	9.300 (35)	9.300 (35)	7.900 (30)	7.300 (28)	6.800 (26)	6.400 (24)	5.700 (22)	8.400 (32)	8.000 (30)	7.600 (29)
<b>440</b>	12.300 (47)	10.300 (39)	10.300 (39)	8.700 (33)	8.000 (30)	7.600 (29)	7.100 (27)	6.300 (24)	9.200 (35)	8.800 (33)	8.360 (32)

<sup>1</sup> UF/MF: Generic Ultra/Microfiltration - continuous filtration process using a membrane with pore size of <0.5 micron.

# System design guidelines



## Design guidelines for 8-inch FILMTEC elements Minimum concentrate flow rate per element

	RO permeate	Well Water	Surface Water			Wastewater			Seawater		
			Dow UF	UF/MF <sup>1</sup>	Conventional	Dow UF	UF/MF <sup>1</sup>	Conventional	Dow UF	UF/MF <sup>1</sup> or Well	Conventional
SDI	<1	<3	<2.5	<3	<5	<2.5	<3	<5	<3		<5
Element type	Minimum concentrate flow rate <sup>2</sup> , gpm (m <sup>3</sup> /h)										
Brackish water (365 ft <sup>2</sup> )	10 (2.3)	13 (3.0)	13 (3.0)	13 (3.0)	15 (3.4)	16 (3.6)	16 (3.6)	18 (4.1)			
Brackish water (400-440 ft <sup>2</sup> )	10 (2.3)	13 (3.0)	13 (3.0)	13 (3.0)	15 (3.4)	18 (4.1)	18 (4.1)	20 (4.6)			
NF	10 (2.3)	13 (3.0)	13 (3.0)	13 (3.0)	15 (3.4)	18 (4.1)	18 (4.1)	18 (4.1)			
Sea water	10 (2.3)	13 (3.0)	13 (3.0)	13 (3.0)	15 (3.4)	16 (3.6)	16 (3.6)	18 (4.1)	13 (3.0)	14 (3.2)	15 (3.4)

<sup>1</sup> UF/MF: Generic Ultra/Microfiltration - continuous filtration process using a membrane with pore size of <0.5 micron

<sup>2</sup> The maximum recommended pressure drop across a single element is 15 psid (1bar) or 50 psid (3.5 bar) across multiple elements in a pressure vessel, whichever value is more limiting. We recommend designing at maximum of 80% (12 psid) for any element in a system.



# System design guidelines



## Design guidelines for 8-inch FILMTEC elements

### Maximum feed flow

		RO Perm eate	Well Water	Surface Water			Wastewater			Seawater		
				Dow UF	UF/M F <sup>1</sup>	Conve ntional	Dow UF	UF/MF <sup>1</sup>	Conve ntional	Dow UF	UF/MF <sup>1</sup> or Well	Conve ntional
<b>SDI</b>		<1	<3	<2.5	<3	<5	<2.5	<3	<5	<2.5	<3	<5
<b>Element type</b>	<b>Area (ft<sup>2</sup>)</b>	Maximum feed flow rate, gpm (m <sup>3</sup> /h)										
<b>Brackish water</b>	365 (33.9)	65 (15)	65 (15)	63 (14)	63 (14)	58 (13)	52 (12)	52 (12)	52 (12)			
<b>NF or Brackish water</b>	400 (37.2)	75 (17)	75 (17)	75 (17)	73 (17)	67 (15)	61 (14)	61 (14)	61 (14)			
<b>Brackish water</b>	440 (40.9)	75 (17)	75 (17)	75 (17)	73 (17)	67 (15)	61 (14)	61 (14)	61 (14)			
<b>Sea water</b>	370 (34.4)	65 (15)	65 (15)	70 (16)	70 (16)	64 (15)	58 (13)	58 (13)	58 (13)	63 (14)		56 (13)
<b>Sea water</b>	380 (35.3)	72 (16)	72 (16)	70 (16)	70 (16)	64 (15)	58 (13)	58 (13)	58 (13)	70 (16)		62 (14)
<b>Sea water</b>	400 (37.2)	72 (16)	72 (16)	70 (16)	70 (16)	64 (15)	58 (13)	58 (13)	58 (13)	70 (16)		62 (14)

<sup>1</sup> UF/MF: Generic Ultra/Microfiltration - continuous filtration process using a membrane with pore size of <0.5 micron



# Ten steps to design a membrane system



- Define product flow rate and recovery (consider feed quality and required permeate quality)
- Select the flow configuration
- Select the membrane element type
- Select the average membrane flux
- Calculate the number of elements needed



# Ten steps to design a membrane system



- Calculate the number of pressure vessels needed
- Select the number of stages
- Select the staging ratio
- Balance the permeate flow rate
- Analyze and optimize the membrane system

# Ten steps to design a membrane system



- Step 1 – Define scope and boundaries
  - Required permeate flow rate
  - Required permeate quality
  - Available feed water quality
  - System recovery
  - Focus on capital or operation costs

# Focus on capital or operation costs



## Focus on minimizing capital costs (CAPEX):

Implications:

- Maximize system flux
- Minimize number of elements and vessels

## Focus on minimizing operational costs (OPEX):

Implications:

- Lower system flux
- Higher number of elements and vessels
- Prefer low energy membranes

# Ten steps to design a membrane system



- Required permeate flow rate
  - Implications:
    - Element size
    - Number of elements
- Required permeate quality
  - Implications:
    - Element selection
    - Flow configuration
    - Recovery

# Ten steps to design a membrane system



- System recovery
  - Seawater recovery limits
    - High osmotic pressure of brine stream
    - Osmotic pressure limits recovery to 35-55%
  - Brackish water recovery limits
    - Brackish waters usually contain sparingly soluble salts which can cause scaling
    - Recovery normally limited to 70-85%
    - Softening or scaling inhibition required
    - Recovery limits for non-treated and softened waters – calculated by ROSA
    - Recovery limits with scale inhibitors – calculated by supplier programs
    - Lower recovery for feeds with higher fouling tendency
  - Permeate quality limits
    - Requested permeate quality may not be achieved at very high recovery

# Ten steps to design a membrane system



- Step 1 – Define scope and boundaries

## OUR EXAMPLE

Required permeate flow rate:	1,000 gpm (227 m <sup>3</sup> /h)
Required permeate quality:	TDS < 20 mg/L
Available feed water quality:	Local river source, TDS = 355 mg/L
System recovery:	80%
Focus on operational costs	

# Ten steps to design a membrane system



- Step 2 – Select flow configuration
  - Continuous process is standard
  - Batch process in special applications – e.g. for separation of process liquids and waste water treatment in food and pharma industries
  - Concentrate recirculation – for small systems and in special application – e.g. waste water or process liquids



# Ten steps to design a membrane system



- Step 2 – Select flow configuration

## OUR EXAMPLE

Continuous process	Yes
Batch process	No
Concentrate recirculation	No

# Ten steps to design a membrane system



- Step 3 – Select the membrane element type

According to:

- System capacity
- Feed water TDS
- Feed water fouling potential
- Required product water quality
- Energy requirements

# Ten steps to design a membrane system



- Step 3 – Select the membrane element type

According to system capacity

- Element diameter for approximate system capacity
  - 2.5-inch < 200 liters/h (1,270 gpd)
  - 4.0-inch < 2.3 m<sup>3</sup>/h (10 gpm)
  - 8.0-inch > 2.3 m<sup>3</sup>/h (10 gpm)
- Element length
  - Standard – 40 inches (1,106 mm)
  - For small compact systems – 21 or 14 inches

# Ten steps to design a membrane system



- Step 3 – Select the membrane element type

According to feed water TDS (rule of thumb)

< 1,000 mg/L	NF270, NF90, XLE, ECO, TW30, XFR, BW30
< 10,000 mg/L	BW30, XFR
10,000-30,000 mg/L	SEAMAXX, SW30ULE, SW30XLE
30,000-50,000 mg/L	SW30HR, SW30XHR, SW30HRLE, SW30XLE

# Ten steps to design a membrane system



- Step 3 – Select the membrane element type

According to feed water fouling potential

- Standard **feed spacer thickness** – **28 mil**
- Feed spacer thickness for feed waters with increased fouling potential – **34 mil** used in BW30-365, BW30-400/34, BW30XFR-400/34, ECO-400, SW30HR-370/34
- **Fouling resistant BW** membrane for biofouling and organic fouling mitigation – used in BW30XFR-400/34, ECO-400

# Ten steps to design a membrane system



- Step 3 – Select the membrane element type

## OUR EXAMPLE

According to:

- System capacity: elements of 8” x 40” (1,000 gpm, 227 m<sup>3</sup>/h)
- Feed water TDS: BW or low energy
- Feed water fouling potential: 34 mil feed spacer
- Required product water quality: BW, ECO, low energy
- Energy requirements: ECO, low energy

# Ten steps to design a membrane system



- Step 4 – Select the average membrane flux

Select the design flux (f) based on:

- Typical design fluxes found in Membrane System Design Guidelines
- Feed water source (type)



# Design Guidelines

## Choosing feedwater type



Feed water type	Description
RO Permeate SDI<1	Very-low-salinity, high-purity waters (HPW) coming from the first RO systems (double-pass RO system) or the polishing stage in ultrapure water (UPW) systems with TDS up to 50 mg/L.
Well Water SDI<3	Water from a ground source that has been accessed via well. Usually, has low fouling potential.
Surface Water with Dow Ultrafiltration SDI<2.5	Water from rivers, river estuaries and lakes. In most cases it has high TSS, NOM, BOD and colloids. Frequently, surface water quality varies seasonally.
Surface Supply SDI<3	
Surface Supply SDI<5	
Wastewater with Dow Ultrafiltration SDI<2.5	Industrial and municipal wastewaters have a wide variety of organic and inorganic constituents. Some types of organic components may adversely affect RO/NF membranes, inducing severe flow loss and/or membrane degradation (organic fouling).
Wastewater with Generic Membrane Filtration SDI<3	
Wastewater with Conventional Pretreatment SDI<5	
Seawater with Dow Ultrafiltration SDI<2.5	Seawater Dow Ultrafiltration as a pre-treatment
Seawater with Generic Membrane Filtration SDI<3	Well -water from a beach well with any type of pre-treatment Seawater any with Generic Microfiltration/Ultrafiltration as a pre-treatment
Seawater (Open Intake) SDI<5	Open intake seawater with conventional pre-treatment

# Ten steps to design a membrane system



- Step 4 – Select the average membrane flux

## OUR EXAMPLE

According to:

- Design guidelines: surface water SDI  $< 5$ ; design flux range = 12-16 gfd (20-27 l/mh) for pretreated river water source
- Conventional pretreatment

# Ten steps to design a membrane system



- Step 5 – Calculate the number of elements needed

$$N_E = \frac{Q_P}{f \cdot S_E}$$

$N_E$	number of elements
$Q_P$	design permeate flow rate of system
$f$	flux
$S_E$	active membrane area of the selected element

## OUR EXAMPLE

$$N_E = \frac{Q_P}{f \cdot S_E} = \frac{5,450(m^3 / day)}{22.3(L / m^2 h) \times 37.2(m^2)} \frac{1day}{24h} \frac{1000L}{1m^3} \approx 274$$

$$N_E = \frac{Q_P}{f \cdot S_E} = \frac{1,440,000(gal / day)}{13.2(gfd) \times 400(ft^2)} \approx 273$$

# Ten steps to design a membrane system



- Step 6 – Calculate the number of pressure vessels needed

$$N_V = \frac{N_E}{N_{EpV}}$$

$N_V$	Number of vessels
$N_E$	Number of elements
$N_{EpV}$	Number of elements per vessel

## OUR EXAMPLE

$$N_V = \frac{274}{7} = 39$$

# Ten steps to design a membrane system



- Step 7 – Select the number of stages

## Number of serial element positions should be higher for:

- Higher system recovery
- Higher fouling tendency

## Number of stages depends on:

- Number of serial element positions
- Number of elements per pressure vessel

# Ten steps to design a membrane system



- Step 7 – Select the number of stages

## Number of stages of a brackish water system

<b>System Recovery (%)</b>	<b>Number of serial element positions</b>	<b>Number of stages (6-element vessels)</b>
40 – 60	6	1
70 – 80	12	2
85 – 90	18	3

# Ten steps to design a membrane system



- Step 8 – Select the staging ratio

$$R = \left[ \frac{1}{(1 - Y)} \right]^{\frac{1}{n}}$$

Y            System recovery (fraction)  
n            Number stages

## OUR EXAMPLE

$$R = \left[ \frac{1}{(1 - 0.80)} \right]^{\frac{1}{2}} \approx 2.24$$



# Ten steps to design a membrane system



- Step 8 – Select the staging ratio

Calculate number of vessels of first stage  $N_v(1)$

$$N_v(1) = \frac{N_v}{1 + R^{-1}}$$

For 2 stage system

$$N_v(1) = \frac{N_v}{1 + R^{-1} + R^{-2}}$$

For 3 stage system

## OUR EXAMPLE

$$N_v(1) = \frac{N_v}{1 + R^{-1}} = \frac{39}{1 + 2.24^{-1}} = 26.9$$

We need approximately 26 vessels in the first stage and 13 vessels in the second stage

# Ten steps to design a membrane system



- Step 9 – Balance the permeate flow rate

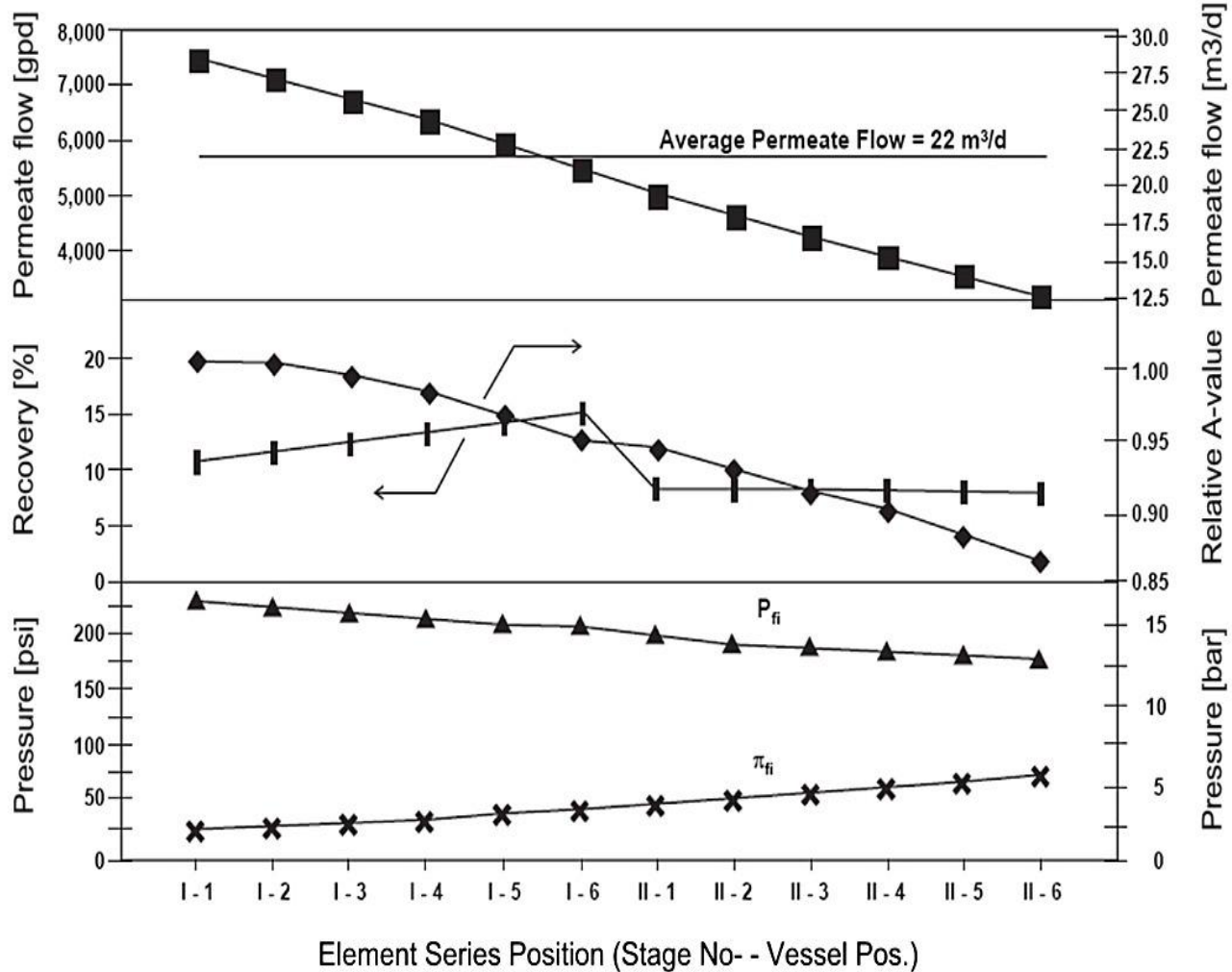
Permeate flow rate per element decreases from the feed end to the concentrate end of the system because of:

- Pressure drop in the feed/concentrate feed spacer
- Increasing osmotic pressure in the feed/concentrate stream

# Ten steps to design a membrane system



Individual element performance in a system 2:1 array of 8-inch BW30 elements (example)



# Ten steps to design a membrane system



- Step 9 – Balance the permeate flow rate

Imbalance of permeate flow rate predominant with:

- High system recovery
- High feed salinity
- High water temperature
- Low pressure elements
- New elements

# Ten steps to design a membrane system



- Step 9 – Balance the permeate flow rate

## Why balance the permeate flow rate?

- Avoid excessive flux of lead elements
- Reduce fouling rate of first stage
- Improve product water quality
- Make better use of tail end elements
- Reduce number of elements

# Ten steps to design a membrane system



- Step 9 – Balance the permeate flow rate

## Methods to balance the permeate flow rate:

- Boosting the feed pressure between stages
- Permeate backpressure to first stage only
- Elements with lower water permeability in the lead positions; elements with higher water permeability in the tail positions

# Ten steps to design a membrane system



- Step 10 – Analyze and optimize the reverse osmosis system

The chosen system should then be analyzed and refined using the Reverse Osmosis System Analysis (ROSA) computer program.



# Questions?

For more information please visit our web site or  
contact your local Dow representative.

<http://www.dowwaterandprocess.com/>

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# RO System Design Webinar Series



## Reverse Osmosis System Design Basics

**Date & Time**  
Sept 9, 2015  
1-3 pm CDT

## RO Webinar Series Speakers:



Scott Beardsley & Steven Coker  
Technical Service Specialists

## Advanced Reverse Osmosis System Design

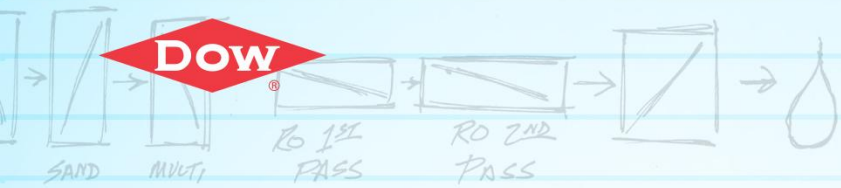
**Date & Time**  
Sept 23, 2015  
1-3 pm CDT

## ROSA System Design Basics

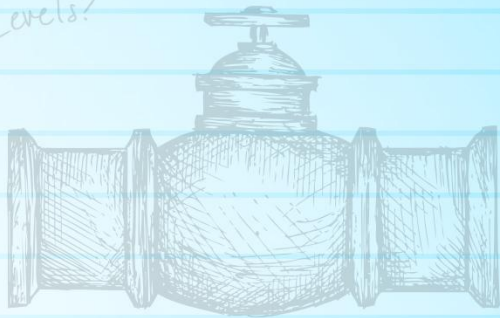
**Date & Time**  
Sept 11, 2015  
1-3 pm CDT

## Advanced RO System Design with ROSA

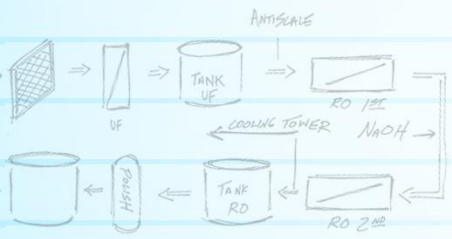
**Date & Time**  
Sept 30, 2015  
1-3 pm CDT



*Expected Conductivity Levels?*

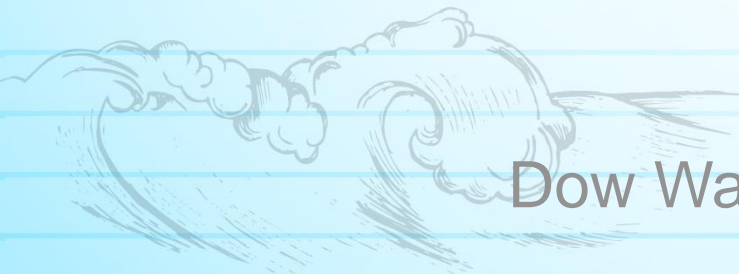
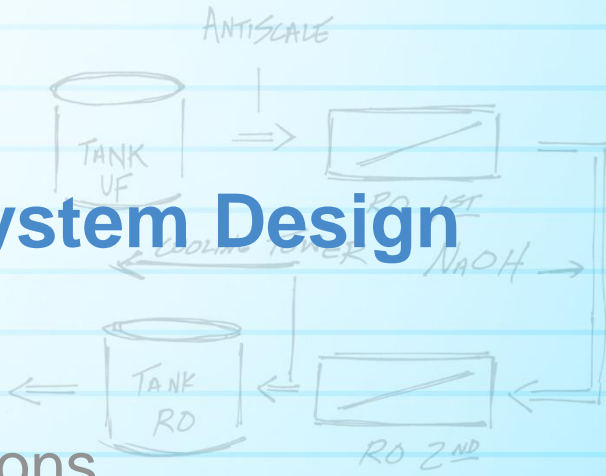


*Deashing  
pH Break vs. Con  
Break - Cycle*



*What are the  
and Water Quality  
Guidelines?*

# Advanced Reverse Osmosis System Design



Steven Coker  
Dow Water & Process Solutions

# Previous Webinars:



## Reverse Osmosis Design Basics – Scott Beardsley

1. Scope of system design
2. System configuration types
3. System design guidelines
4. Ten steps to design a membrane system



Previous Water Academy webinars can be found at:

[www.dowwaterandprocess.com](http://www.dowwaterandprocess.com)

# Overview of Advanced RO Design



- RO system design guideline variables
- Drivers for RO system configuration selection
- Principles and benefits of RO array flux balancing
- Array selection criteria to achieve permeate quality target
- Energy recovery



# Dichotomy of RO System Design



## Focus on minimizing capital costs (CAPEX):

Implications:

- Maximize system flux
- Minimize number of elements and vessels

## Focus on minimizing operational costs (OPEX):

Implications:

- Lower system flux
- Higher number of elements and vessels
- Prefer low energy membranes

**Achieve the required permeate quality  
at the lowest total cost of water**

# Complexity of RO Designs



## VARIOUS APPLICATIONS

### Industrial/ Power/UPW

1<sup>st</sup> & 2<sup>nd</sup> pass



### Wastewater Reuse

1<sup>st</sup> & 2<sup>nd</sup> pass



### Irrigation

1<sup>st</sup> pass



### Municipal Potable

1<sup>st</sup> pass



### SWRO

1<sup>st</sup> & 2<sup>nd</sup> Pass



## VARIOUS FEED WATER SOURCES

- Waste water
  - Conventional
  - UF
- Surface water
  - Conventional
  - UF
- Well water
- RO permeate



Increasing  
Fouling  
Potential

## VARIOUS QUALITY REQUIREMENTS

- B < 0.3-1 mg/l
- Br < 0.1 mg/l
- TOC < 10 ppb
- NO<sub>3</sub> < 0.5 -35 mg/l
- NH<sub>4</sub> < 0.5 mg/l
- SiO<sub>2</sub> < 10 ppb
- Hardness 0.5 mg/l - 200 mg/l CaCO<sub>3</sub>
- TDS: 0.1 mg/l - 500 mg/l

Global  
Market  
Global  
Project  
Development



Regional  
Preferences

Regional  
Regulations

Strong  
Regional  
Variations

(TDS/Temp)



# Market Segment Nuances for RO Design



## Municipal

- Medium to large size plants
- Wide permeate quality targets
- Total cost of water is most critical



- Greater latitude in system design
- Larger selection of RO elements



## Industrial

- Small to medium size plants
- Narrow permeate quality targets
- System reliability is most critical



- Narrow latitude in system design
- High rejection RO elements



# Membrane Design Guidelines



Happy RO Elements Work Better and Live Longer!



## Design Guideline Variables

### Feed Water Variables

- Temperature
- pH
- Silt Density Index
- Turbidity
- Salinity

### System Variables

- Element Flux
- Element Feed Flow
- Differential Pressure
- Element Recovery
- System Recovery
- Operating Pressure

# Membrane Design Guideline Variables



## Feed Water Variables

- Temperature
- pH
- Silt Density Index
- Turbidity
- Salinity

## System Variables

- Element Flux
- Element Feed Flow
- Differential Pressure
- Element Recovery
- Operating Pressure

## Design Considerations

- Min T = Max P; Max T = Max TDS & Flux
- Rejection; Rejection of spec. ions; Scaling
- Fouling potential; Pretreatment
- Fouling potential; Pretreatment
- Membrane choice; Recovery; Pressure
  
- Number of RO elements and vessels
- Differential pressure; Number of vessels
- Num. of elements/vessel; Spacer; Life
- System recovery; Salinity; flux balance
- OPEX; Salinity; Temperature; Flux; Area;

# Membrane Element Selection



According to feed water fouling potential

- Standard feed spacer thickness: 28 mil
- Feed spacer thickness for feeds with increased fouling potential: 34 mil
- Fouling resistant BW membrane for biofouling control

# Membrane Element Selection



According to required product water quality and energy requirements

Higher salt passage



Lower Salt passage

- NF270
- NF90
- XLE
- LE
- XFRLE
- HRLE
- BW30 / TW30
- ECO
- BW30XFR
- BW30HR
- SEAMAXX
- SW30ULE
- SW30XLE
- SW30HR
- SW30HRLE
- SW30XHR

Lower feed pressure



Higher feed pressure

# Selecting RO System Configuration



## Typical RO System and Element Selection Drivers

- Controlling RO array flux balance
- RO fouling/scaling mitigation
- Required permeate or concentrate quality
- Optimization of RO system energy consumption

**Typically, all of these selection drivers have an impact on the final RO system design.**

# Configuration – Number of stages selection



## **Number of serial element positions should be higher for**

- Higher system recovery
- Higher fouling tendency of the feed water

## **Number of stages depends on**

- Number of serial element positions
- Number of elements per pressure vessel

# Configuration – Number of stages selection



## Number of stages of a brackish water system

System Recovery (%)	Number of serial element positions	Number of stages (6-element vessels)
40 – 60	6	1
70 – 80	12	2
85 – 90	18	3

## Number of stages of a sea water system

System Recovery (%)	Number of serial element positions	Number of stages (6-element vessels)	Number of stages (7-element vessels)	Number of stages (8-element vessels)
35 - 40	6	1	1	-
45	7 - 12	2	1	1
50	8 - 12	2	2	1
55 – 60	12 - 14	2	2	-

# Multistage systems: Staging ratio calculation



$$R = \left[ \frac{1}{(1 - Y)} \right]^{\frac{1}{n}}$$

**Y**  
**n**

**System recovery (fraction)**  
**Number stages**

$$R = \frac{N_v(i)}{N_v(i + 1)}$$

**R**  
 **$N_v(i)$**   
 **$N_v(i + 1)$**

**Staging ratio**  
**Number of vessels in stage i**  
**Number of vessels in stage (i + 1)**

**Calculate number of vessels of first stage  $N_v(1)$**

$$N_v(1) = \frac{N_v}{1 + R^{-1}}$$

**For 2 stage system**

$$N_v(1) = \frac{N_v}{1 + R^{-1} + R^{-2}}$$

**For 3 stage system**



# Multistage Systems: Staging Ratio



Typical staging ratio:

- 1.5**      sea water systems with 6-element vessels
- 2**        brackish water systems with 6-element vessels
- 3**        low feed salinity or 2<sup>nd</sup> pass RO systems

# Multi-stage Systems: Managing Flux Balance



## Why balance the permeate flow rate?

- Avoid excessive flux of lead elements
- Reduce fouling rate of first stage
- Make better use of tail end membranes
- Reduce number of elements
- Improve product water quality

## Methods to balance the permeate flow rate

- Boosting the feed pressure between stages
- Permeate backpressure to first stage only
- Membranes with lower water permeability in lead positions - membranes with higher water permeability in tail positions

# Advanced RO System Design Options



## Managing Flux Balance

- Stage 1 permeate backpressure or stage 2 boost pump
- Multi-element hybrid array
- Internally Staged Design (ISD) array

## Managing Permeate Quality

- RO with feed water/permeate blending
- 2 pass RO system
- 2 pass RO system w/ partial 2<sup>nd</sup> pass
- 2 pass RO system w/ permeate split design

# Stage-wise Flux Balancing

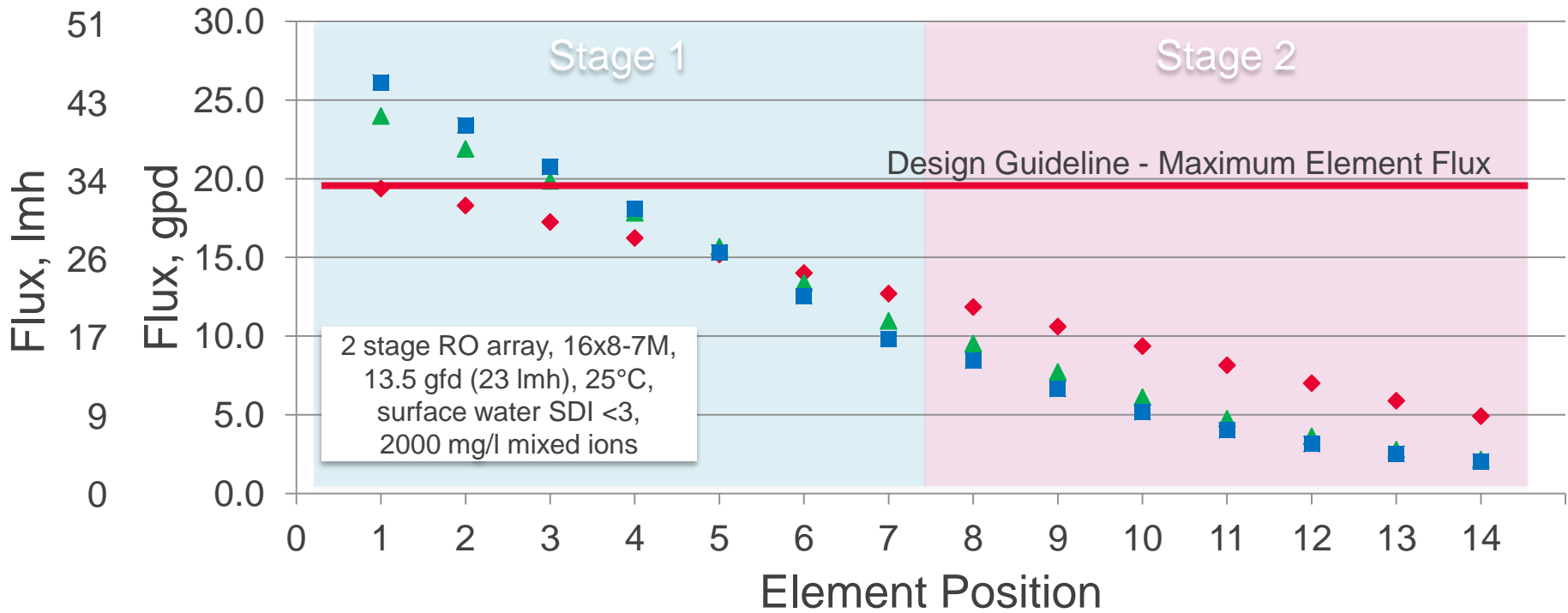


## Element Flux Across 2 Stage Array

◆ 7,550 gpd  
(28.6 m<sup>3</sup>/d)

▲ 12,650 gpd  
(47.9 m<sup>3</sup>/d)

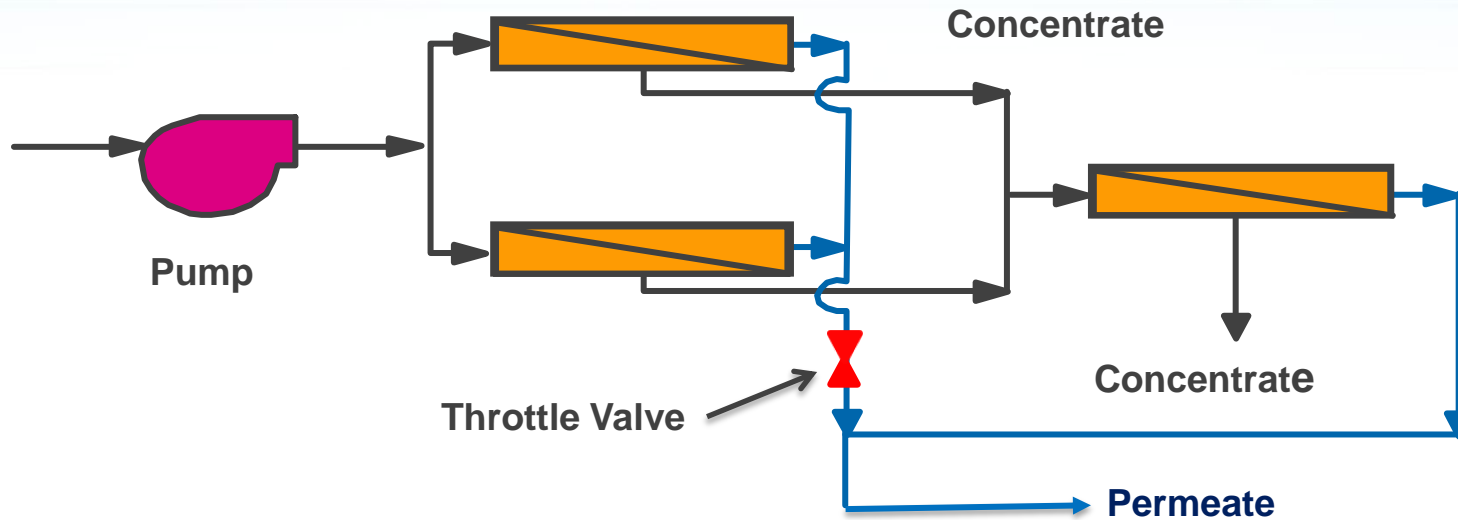
■ 15,100 gpd  
(57.2 m<sup>3</sup>/d)



Element gpd tested at 150 psig (10.3 barg), 2000 mg/l NaCl, 25°C, pH 8, 15% recovery



# Balancing Flux with Stage 1 Permeate Pressure



$$NDP = P_{feed} - \frac{DP}{2} - OP_{fb} - P_p + OP_p$$

Where:

- $NDP$  = Net Driving Pressure (psig)
- $P_{feed}$  is feed pressure (psig)
- $DP$  is differential pressure (psig)
- $OP_{fb}$  is feed-brine osmotic pressure (psig)
- $P_p$  is permeate pressure (psig)
- $OP_p$  is permeate osmotic pressure (psig)

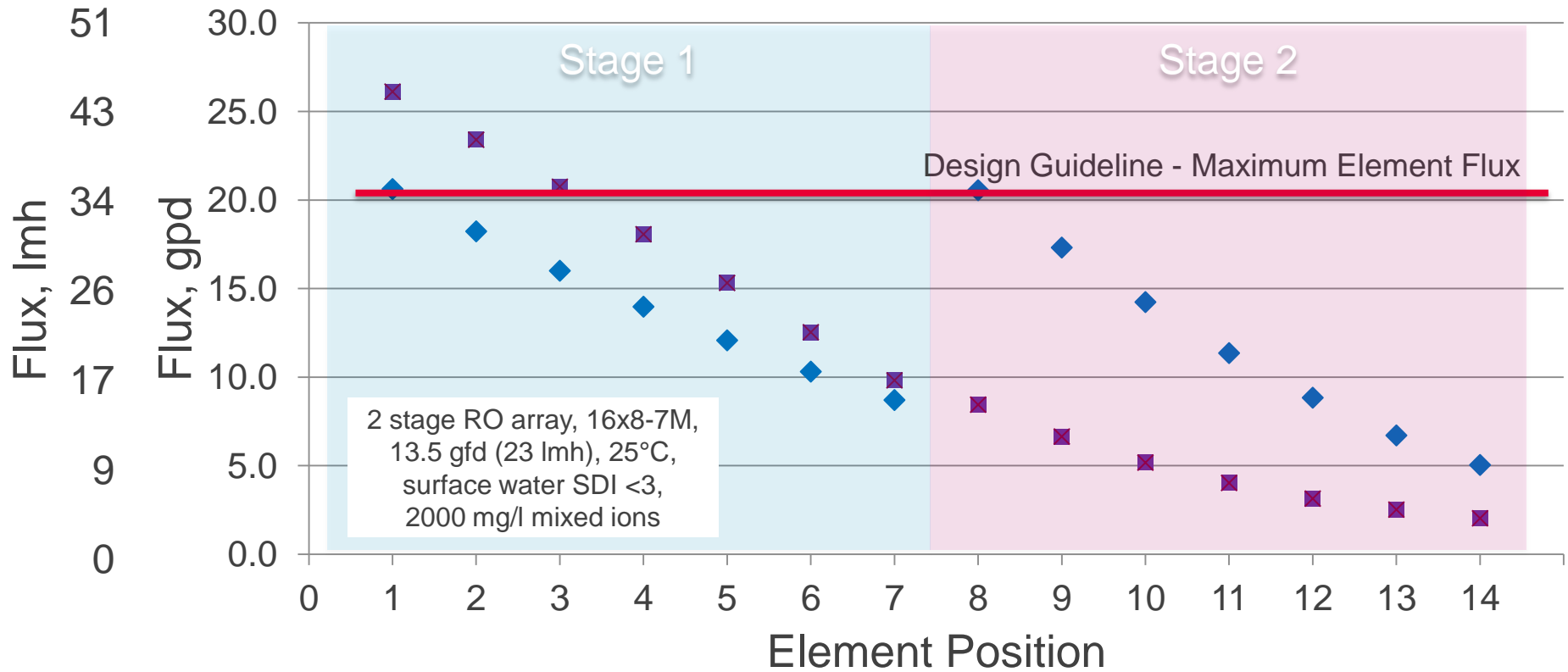
# Balancing Flux with Stage 1 Permeate Pressure



## Element Flux Across 2 Stage Array

■ 15,100 gpd  
(57.2 m<sup>3</sup>/d)

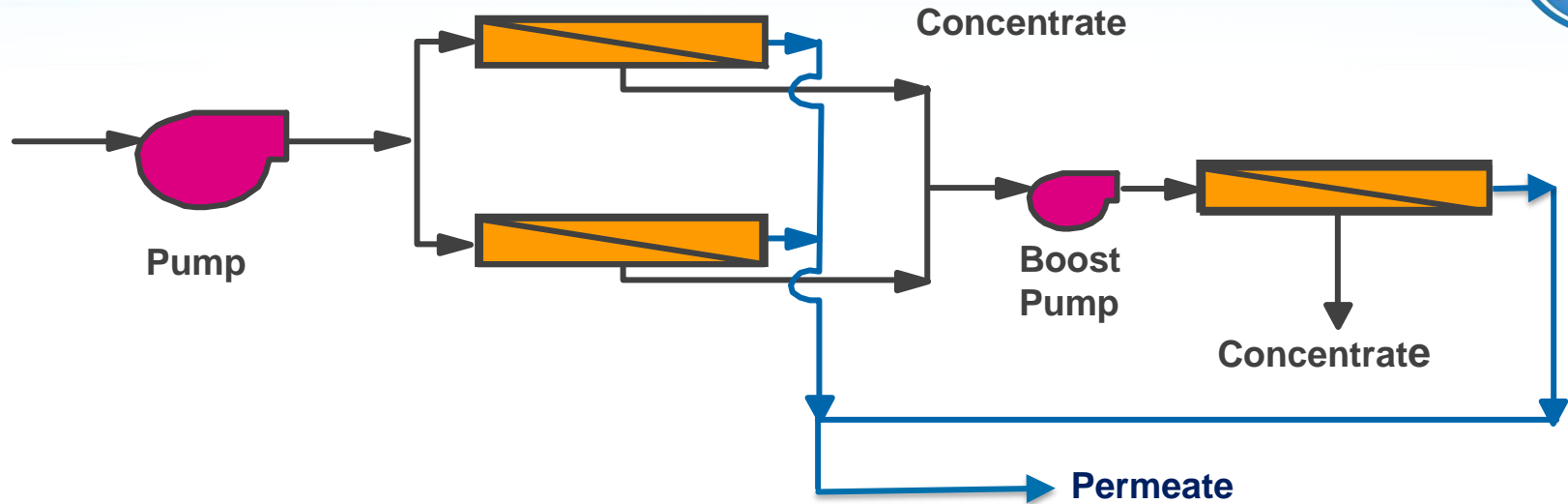
◆ 15,100 gpd w/ Perm. Throt.  
(57.2 m<sup>3</sup>/d)



Element gpd tested at 150 psig (10.3 barg), 2000 mg/l NaCl, 25°C, pH 8, 15% recovery

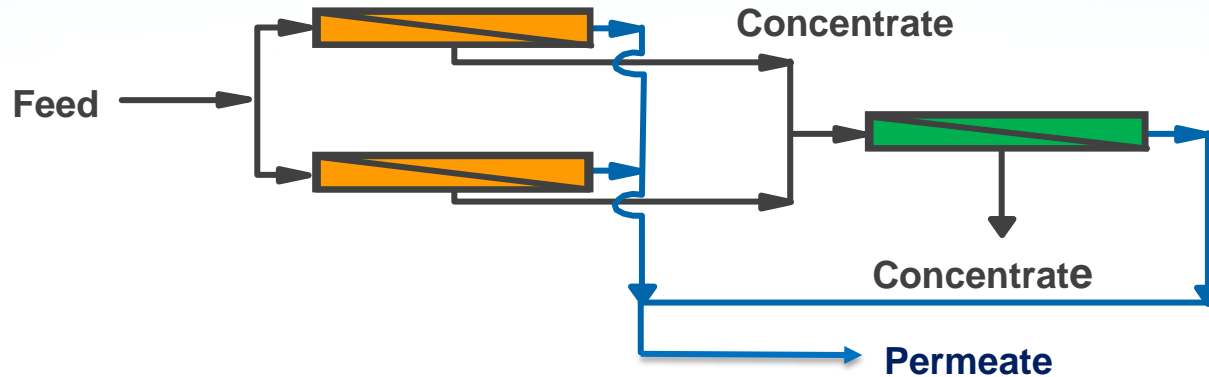


# Balancing Flux with Stage 2 Boost Pump



- Boost pump can be driven by electricity or by energy recovery device
- Stg 2 boost pressure = Stg 1 permeate throttle pressure
- Throttle valve is less expensive than boost pump
- Throttle valve has higher energy cost
- Throttle valves are typically limited to smaller systems

# Multi-Element Hybrid Array



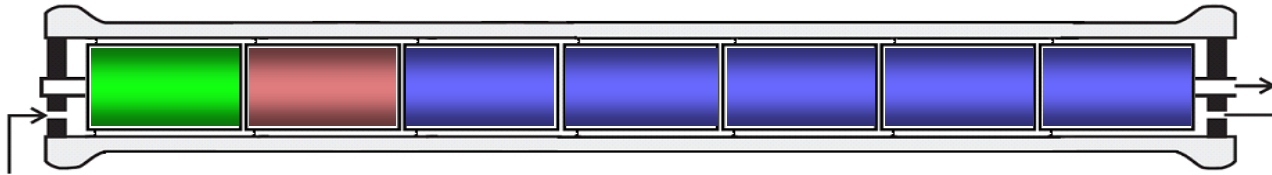
- Using different RO elements in each stage of the array...
  - to improve the flux balance between stages
  - to increase or decrease permeate TDS



# Internally Staged Design (ISD) RO Array

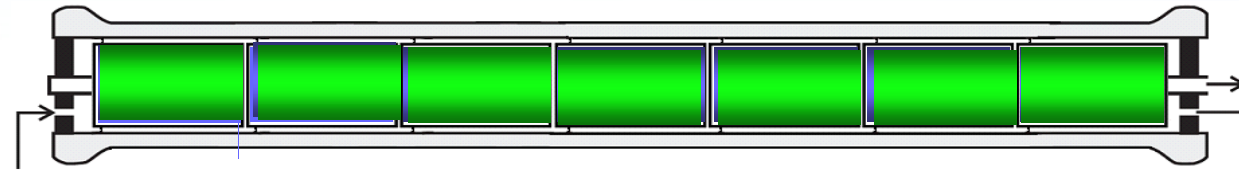


## Internally Staged Design

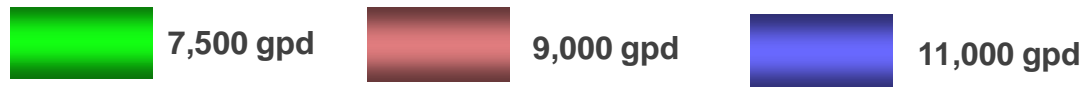
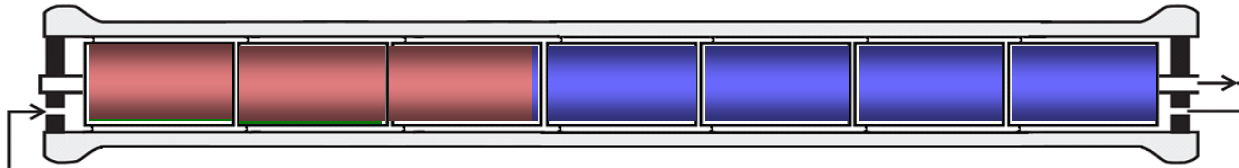
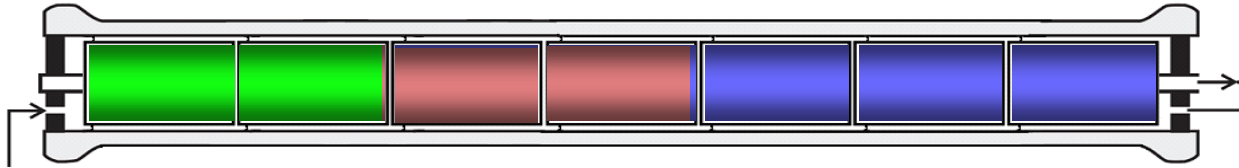
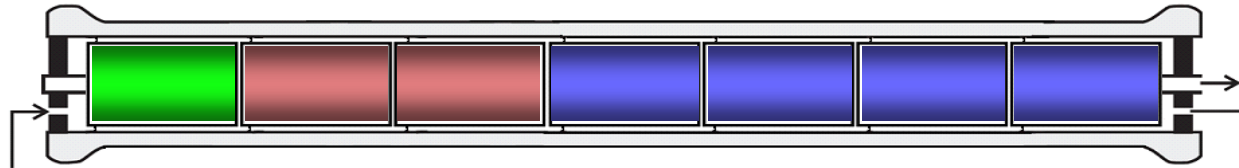
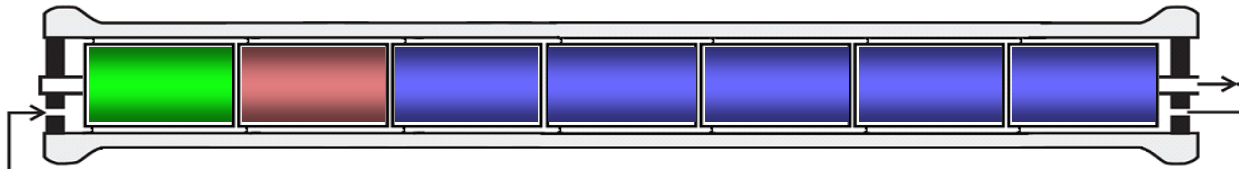


- Multiple RO element types used in a stage
- Common method to control element flux and to optimize energy consumption in seawater systems
- Common method to minimize post-treatment chemical addition in municipal drinking water RO/NF systems

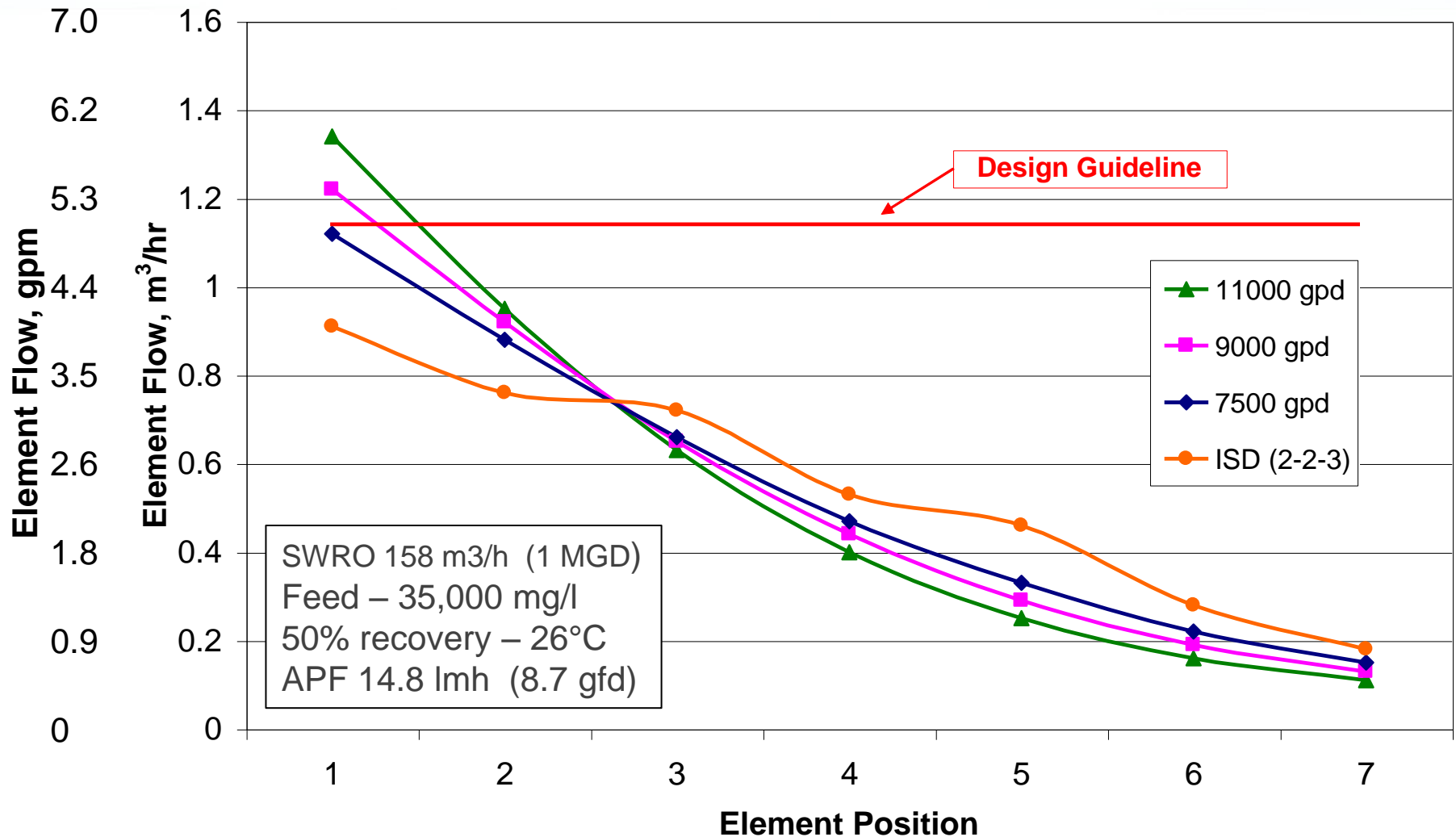
# SWRO Element Loading Options



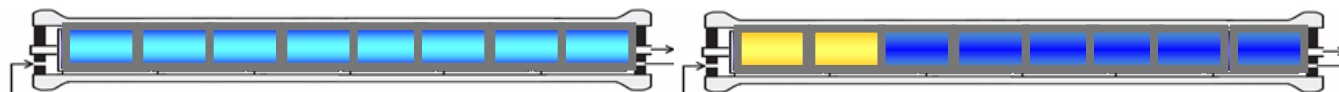
Examples of Potential FILMTEC™ ISD Element Loading Options



# Using ISD to Optimize SWRO Performance



# Configuration – Internally Staged Design



Average Flux of the vessel	14 lmh (8.2 gfd)	15.8 lmh (9.2 gfd)
Maximum permeate flow per element	0.99 m <sup>3</sup> /h (4.4 gpm)	0.99 m <sup>3</sup> /h (4.4 gpm)
COST of Water Highest FF & T	60.14 UScts/m <sup>3</sup> (228 UScts/kgal)	58.27 UScts/m <sup>3</sup> 221 UScts/kgal)
COST of Water Lowest FF & T	63.65 UScts/m <sup>3</sup> (241 UScts/kgal)	60.05 UScts/m <sup>3</sup> 227 UScts/kgal)
% savings on cost of water*	Highest FF & T Lowest FF & T	3.1% 5.7%

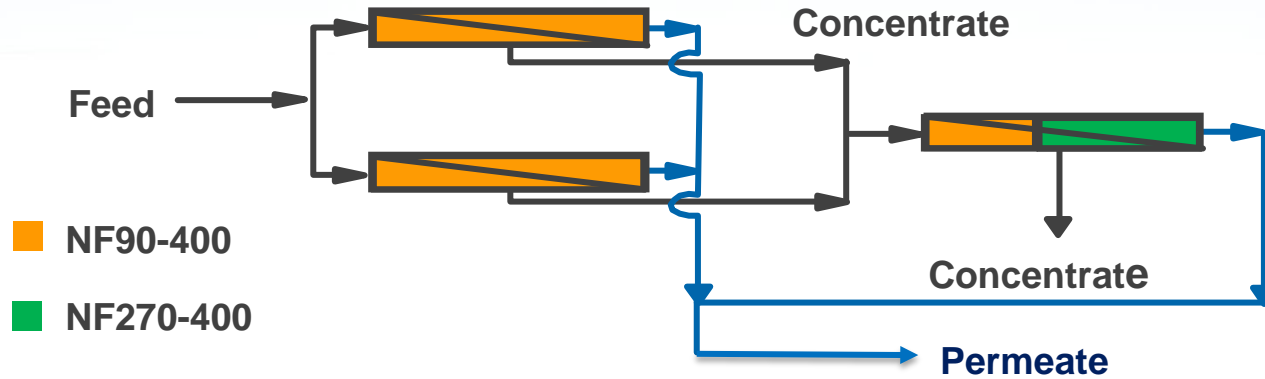
 SW30HRLE-400i

 SW30XHR-400i

 SW30ULE-400i

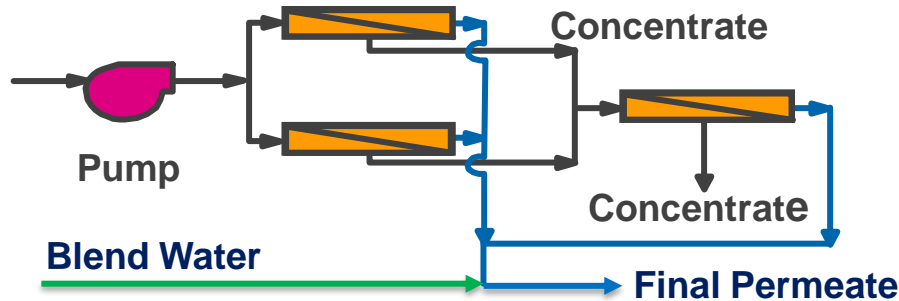
\* **COST CALCULATION (TOOLS):** CAPEX and OPEX are taken into account. Model is prepared by a Consulting Company\* for Dow (*John Tonner Water Consultants International Inc.*)

# Using ISD to Minimize Post Treatment



- Municipal NF plant designed with multiple 44 x 22 – 7M trains with FILMTEC™ NF90-400 elements.
- The plant installed 4 NF270-400 elements in second stage to increase passage of hardness and alkalinity.
- Resulting increase in permeate total hardness and alkalinity levels allowed plant to eliminate problematic chemical addition in post treatment saving an estimated \$1M/year in O&M costs.

# RO with Feed Water/Permeate Blending



- Common in drinking water plants
- Increase overall system throughput
- Minimize post-treatment chemicals
- Blend water quality is critical
  - Determines the blend ratio
  - Low color
  - Low TOC and DBPFP

## Sources of Blend Water

- Raw water
- RO feed water
- Lime softened water
- Permeate from different system

# Economic Impact of Permeate Blending



	XLE-440	ECO-440i w/ Blend
Rejection	99.0%	99.7%
Element Flow	14,000 gpd	12650 gpd
Test Conditions	125 psig – 2000 mg/l NaCl	150 psig – 2000 mg/l NaCl
Array	16 x 8 – 7M	14 x 7 – 7M
Flux	13.5 gfd	13.5 gfd
RO Recovery	80%	80%
System Recovery	80%	82%
Final TDS	72 mg/l	207 mg/l
Final Total Hardness	24 mg/l as CaCO <sub>3</sub>	91 mg/l as CaCO <sub>3</sub>
RO Specific Energy	1.22 kWh/kgal	1.11 kWh/kgal

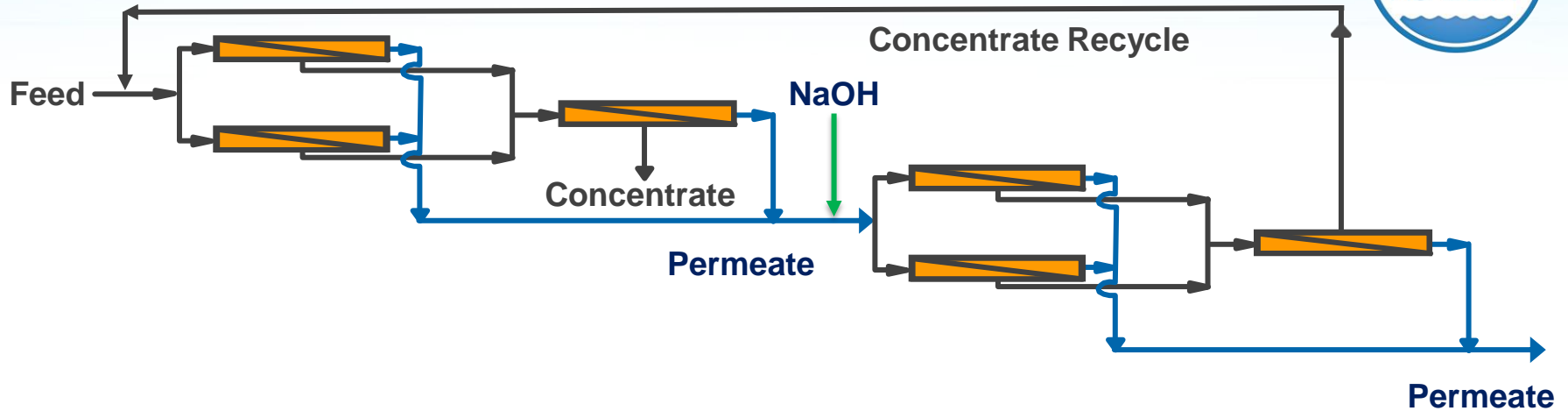
## CAPEX Savings

- 12.5% fewer vessels
- 12.5% fewer elements

## OPEX Savings

- 9% lower energy
- Reduced post-treatment

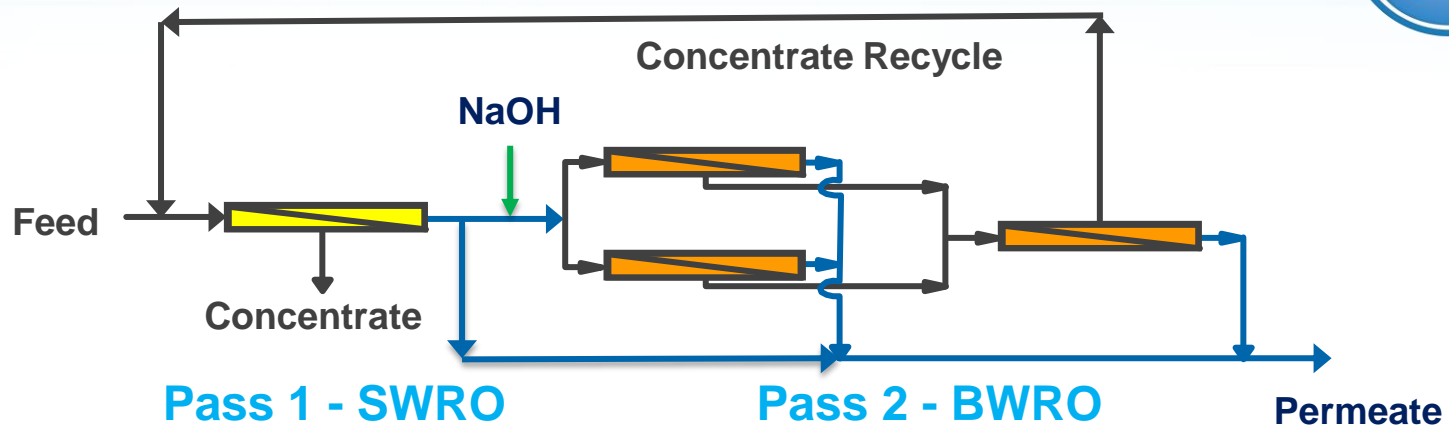
# 2 Pass RO Design



- 2 pass RO systems are primarily used when high purity permeate is required.
- Typical applications include boiler feed water, semiconductor rinse water, some seawater municipal plants, etc.
- Inter-pass pH adjustment with sodium hydroxide is commonly used to enhance rejection of alkalinity, boron, etc.

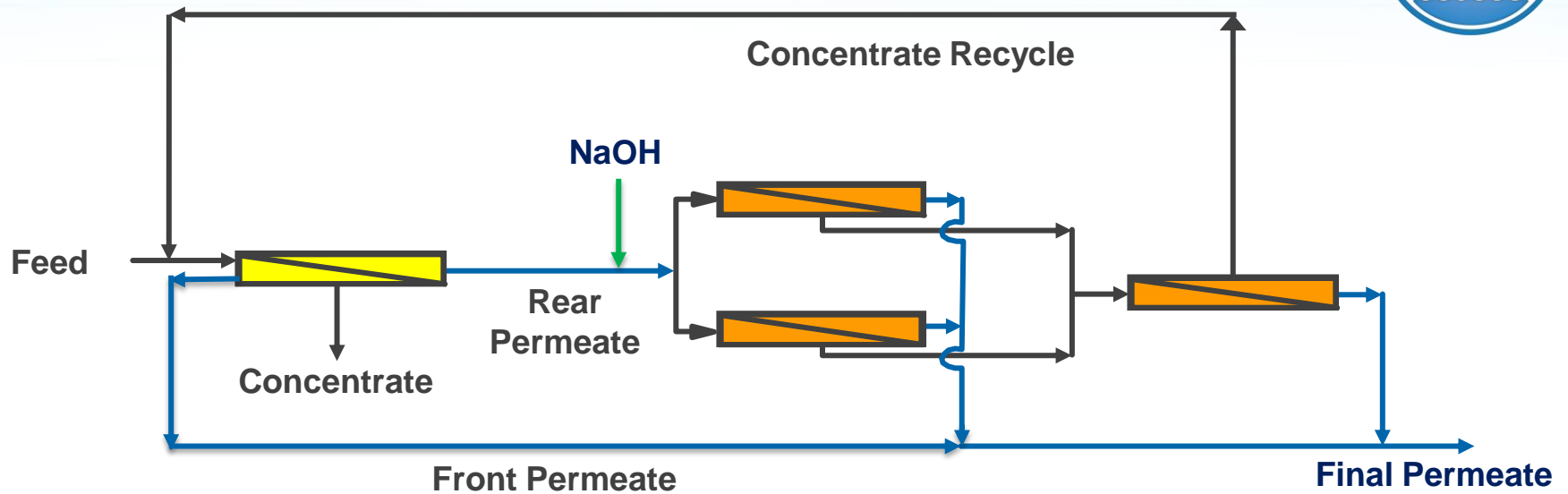


# SWRO Design with Partial 2nd Pass



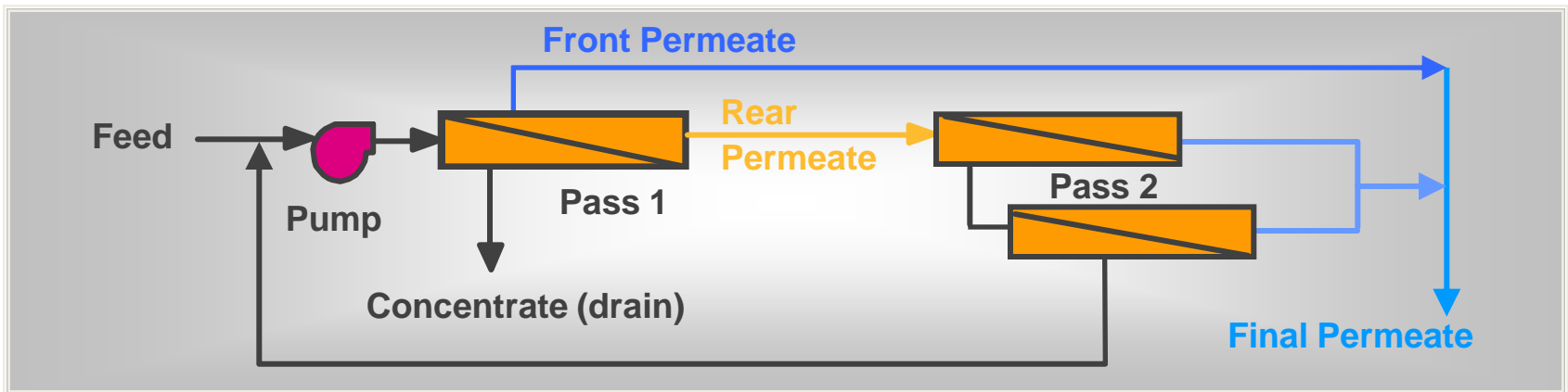
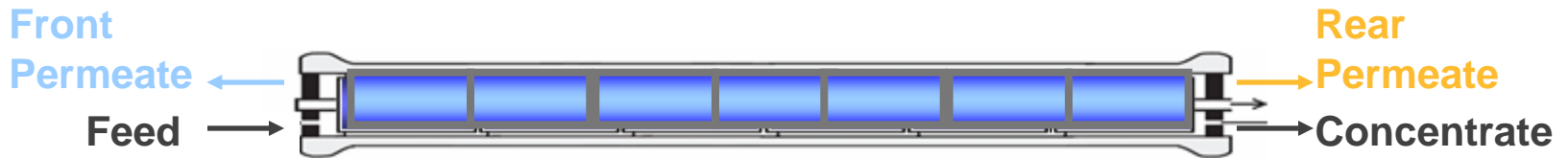
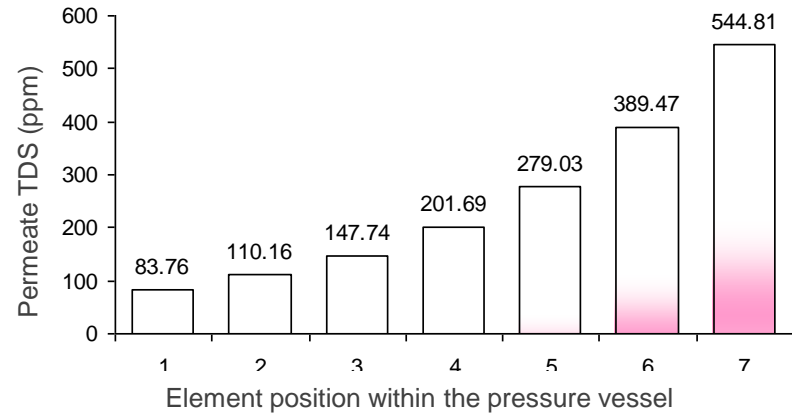
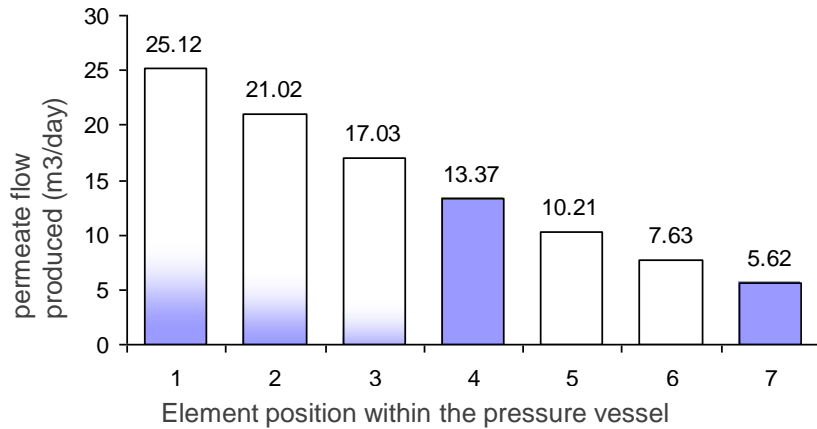
- SWRO design with a partial 2<sup>nd</sup> pass is primarily used to produce municipal drinking water
- This design saves both CAPEX and OPEX
- Percentage of 1<sup>st</sup> pass permeate treated with 2<sup>nd</sup> pass is a function of the feed water salinity and required final permeate salinity

# Split Permeate SWRO – Partial 2 Pass



- Split permeate SWRO systems withdraw permeate from both ends of the first stage pressure vessels
- Front permeate is lower in salinity and is directly blended into the final permeate stream
- Ratio of front/rear permeate is typically controlled by pass 2 feed pump
- Many split permeate SWRO systems use ISD with elements chosen specifically to reduce front permeate TDS and/or control lead element flux

# Double pass with permeate split-stream



# Energy Recovery



- Energy Recovery Devices (ERD) are used to capture and use residual concentrate stream pressure to:
  - Increase feed pressure prior to final high pressure pump (HPP)
  - Augment electrical drive motor on HPP
  - Provide inter-stage boost pressure on multi-stage RO and NF
- ERDs are used on virtually all SWRO plants and many BWRO plants to reduce power costs of RO
- Several manufacturers have combining ERDs with pumps in small configurations which make it economical to use energy recovery on both smaller and low pressure systems
- Concentrate streams can be combined from multiple low pressure trains to drive ERD on single HPP

# Examples of ERDs



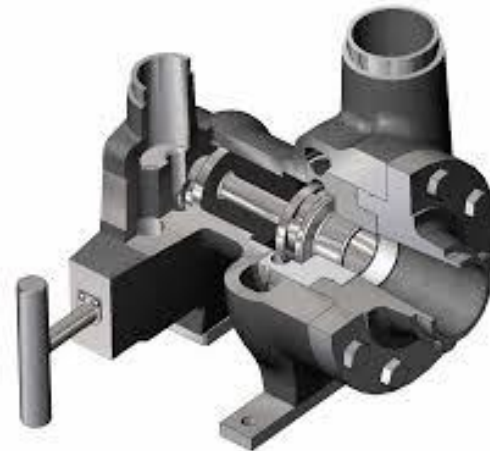
Pelton Wheel



DWEER Work Exchanger



ERI PX



FEDCO Turbine

# Available Energy for Recovery Calculation



- All ERD manufacturers have sophisticated computer models to incorporate ERDs into systems
- Below is a simple equation to estimate available boost pressure from an ERD in an RO system.

$$P_{avail} = P_c * \frac{Q_c}{Q_f} * Eff$$

$P$  = pressure

$Q$  = flow rate

$Eff$  = ERD efficiency

Subscripts:

avail = available

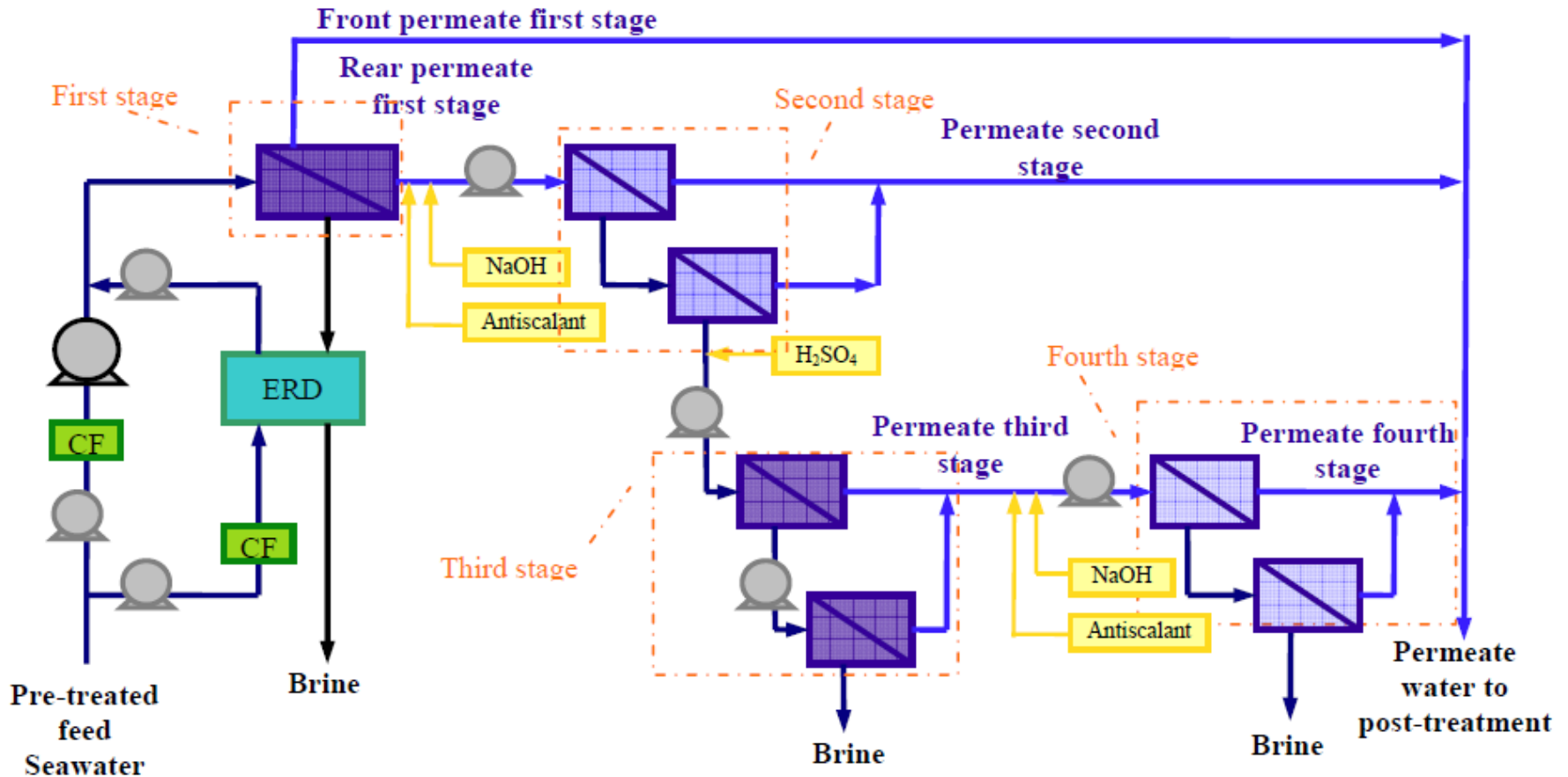
c = concentrate

f = feed

# Advanced RO Design Example



Diagram of IDE's Patented Cascade Process



KEY ASPECTS OF THE MEMBRANE TECHNOLOGY IMPLEMENTED IN THE CARLSBAD DESALINATION PROJECT

Authors: Eduard Gasia Bruch, Steven Coker, Boaz Keinan, Blanca Salgado  
 Presented at the IDA World Congress 2015, San Diego, CA, USA. August 30 – September 4, 2015



# Further Help – Answer Center



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### Advanced Search

Search our knowledge base

blending

Search

### Search filters applied

Product

FILMTEC RO / NF Elements

Results 1 - 5 of 5 for blending

#### Summary

- FILMTEC Membranes - **Blending** in ROSA
- FILMTEC Membranes - Definition of % Recovery
- FILMTEC Membranes - ROSA - Permeate Split
- FILMTEC Membranes - High Rejection Seawater Elements Resist Fouling, Cut TDS and Costs (Case History)
- FILMTEC Membranes - Design - Reduce Plant Capacity to Obtain Just Required Permeate Quality

## Contact Us

### Ask the Expert

Submit a question to our support team.

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If you can't find what you're looking for on our site, give us a call.

### Give Feedback

How can we make this site more useful for you?





# Summary



- RO is a highly versatile technology with many choices for optimization of CAPEX and OPEX
- Most important for a plant designer is to understand the starting point and customer's preferences
- Design within element operating guidelines and system guidelines for optimal performance and element life
- Recent advances in membrane chemistry and RO element construction enables several innovative designs
- Innovation continues...
- Seek out to Dow for guidance

# RO System Design Webinar Series



## Advanced Reverse Osmosis System Design

### **Date & Time**

Sept 23, 2015  
1-3 pm CDT



Steven Coker  
Technical Service Specialist

## Advanced RO System Design with ROSA

### **Date & Time**

Sept 30, 2015  
1-3 pm CDT



Sign up today!

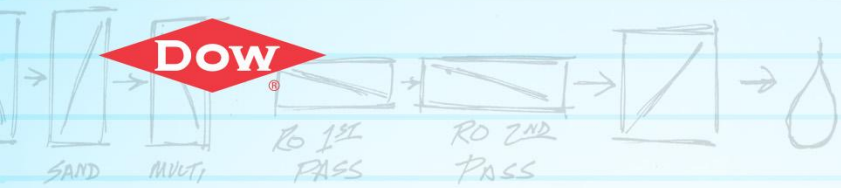
# Questions?

For more information please visit our web site or  
contact your local Dow representative.

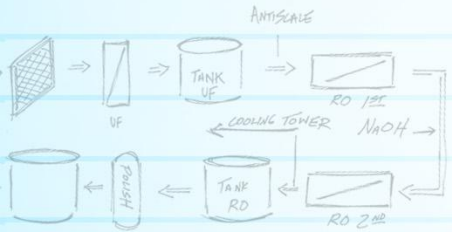
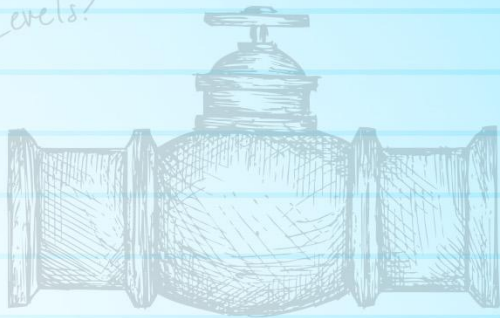
<http://www.dowwaterandprocess.com/>

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*Expected Conductivity Levels?*

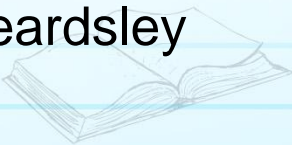
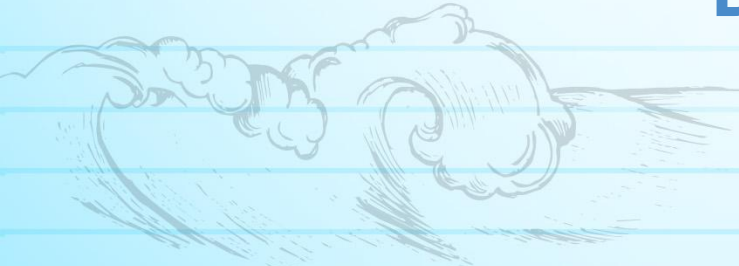
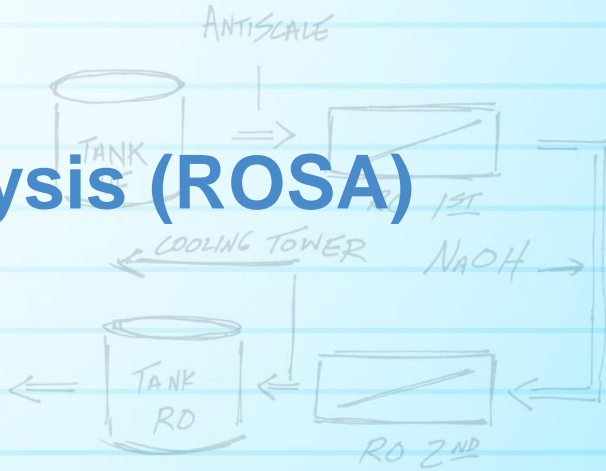


*pH Break vs. Con Break - Cycle*

*What are the standard Water Quality Guidelines?*

# Reverse Osmosis System Analysis (ROSA) Design Basics

Scott Beardsley





# RO System Design Webinar Series



## Reverse Osmosis System Design Basics

**Date & Time**  
Sept 9, 2015  
1-3 pm CDT

### RO Webinar Series Speakers:



Scott Beardsley & Steven Coker  
Technical Service Specialists

## Advanced Reverse Osmosis System Design

**Date & Time**  
Sept 23, 2015  
1-3 pm CDT

## ROSA System Design Basics

**Date & Time**  
Sept 11, 2015  
1-3 pm CDT

## Advanced RO System Design with ROSA

**Date & Time**  
Sept 30, 2015  
1-3 pm CDT

# Reverse Osmosis System Analysis (ROSA)



- **What is it?**

ROSA—the industry-leading RO system design tool for decades—makes it easy for you to design a reverse osmosis plant to meet your required water treatment specifications.

- **How does it work?**

Enter the concentration of ions in the feed water, select the type of FILMTEC™ element, and try different vessel configurations. ROSA does all the complex math for you and produces a complete, but simple-to-understand, report predicting the water quality and flow rate.

# ROSA – Introduction to RO Plant Design



- Project Information
- Feedwater Data
- Scaling Information
- System Configuration
- Report

# ROSA – Control Panel: File



ROSA Control Panel - Project 8956

System Pemeate Flow: 0.20 m<sup>3</sup>/h    System Feed Flow: 1.33 m<sup>3</sup>/h    System Recovery: 15.00%

File    Options    Help

- New Project
- Open Project
- Close Project
- Save Project
- Save As
- Exit

Project Name: Project 8956

Project Cases

Case: 1    Add Case    Delete Case    Pre-stage ΔP: 0.345 bar

Notes for Current Case:

Highest Fouling Factor + Highest Temperature, LE elements

Project Preferences

Analysis By: Jane Doe     Small Commercial System

Company Name: Water Filtration 123

Balance Analysis With: NaCl

Units Set: Flow: m<sup>3</sup>/h, Pressure: bar

Temperature Unit: Celsius (°C)

Default Project Folder: C:\Program Files\ROSA70\MyProjects

1) Project Information    2) Feedwater Data    3) Scaling Information    4) System Configuration    5) Report    6) Cost Analysis

Monday, September 28, 2009    Ready...





# ROSA – Control Panel: Options

The screenshot shows the ROSA Control Panel interface. The 'Options' menu is open, with 'User Data' selected. A red arrow points from 'User Data' to the 'User Data Settings' dialog box. The dialog box contains the following information:

Notes: The settings made here will be shown on the Project Information tab, and persist through each use of the program.  
Interface language changes require closing the program and restarting.

Your Name: Jane Doe  
Company: Water Filtration 123  
Balance Chemical: NaCl

User Interface Language: English

See note above.

Report Language: English

Default Units:  
Flow, Pressure: Flow: m3/h, Pressure: bar  
Temperature: Flow: gpm, Pressure: psig  
Flow: gpd, Pressure: psig  
Flow: m3/h, Pressure: bar  
Flow: m3/d, Pressure: bar

Color Scheme: Classic

Buttons: Cancel, Save and Close

User Data Settings – stores introduced and selected information

# ROSA – Control Panel: Options



**ROSA Control Panel**

File Options Help

Batch Processor Premeate Flow:

Database

Files and Folders

User Data

Project Cases

Notes for Current Case: Case: 1

Project Preferences

Analysis By: Justyna Warczok

Company Name: The Dow Chemical C

Balance Analysis With: NaCl

Units Set: Flow: m3/h, Pressur

Temperature Unit: Celsius (°C)

Default P

**File and Folder Options**

The following settings allow you to choose how you want ROSA to handle input (.rosa) files, and output (.html) files.

When opening a .rosa project file (File/Open Project)

- Open the folder most recently used during a ROSA file operation (opening or saving)
- Open the default folder: C:\Documents and Settings\U391938\Data\My Documents\DWS\Technical

When saving a .rosa project file (File/Save As)

- Save in the folder most recently used during a ROSA file operation (opening or saving)
- Save in the default folder: C:\Documents and Settings\U391938\Data\My Documents\DWS\Technical

Save the output .html files (detail and overview)

- Save output files in the default folder C:\Documents and Settings\U391938\Data\My
- Save output files in the same folder as the input file (if applicable)
- Save output files in:

Set my own default folder for .rosa files

C:\Documents and Settings\U391938\Data\My Documents\DWS\Technical Service\Tech Request\RO\Projections

Save and Close

When first opened it shows where the ROSA files are stored by default

Can be changed according to the personal preferences

Tuesday, July 20, 2010 Ready...

# ROSA – Control Panel: Help



The screenshot shows the ROSA Control Panel software interface. The main window has a menu bar with 'File', 'Options', and 'Help'. The 'Help' menu is open, showing options: 'About ROSA', 'FilmTec Website', 'Help', 'Unit Conversion', and 'Show Welcome Screen at Startup'. A red arrow points from the 'Unit Conversion' menu item to the 'Units Converter' dialog box. The dialog box has two sections: 'Flow' and 'Pressure'. The 'Flow' section shows 'From Unit' as 'gpm' and 'To Unit' as 'm³/h', with a value of 123 gpm converted to 27.9333 m³/h. The 'Pressure' section shows 'From Unit' as 'psig' and 'To Unit' as 'bar', with a value of 123 psig. The background software interface includes fields for 'System Feed Flow: 1.33 m³/h' and 'System Recovery: 15.00%'. There are sections for 'Project Information', 'Project Cases', and 'Project Preferences'. The 'Project Preferences' section includes fields for 'Analysis By:', 'Company Name:', 'Balance Analysis With:' (set to NaCl), 'Units Set:' (Flow: m3/h, Pressure: bar), 'Temperature Unit:' (Celsius (°C)), and 'Default Project Folder:' (C:\Program Files\ROSA70\MyProjects). The 'DOW Water & Process Solutions' logo is visible in the center. At the bottom, there is a navigation bar with tabs: '1) Project Information', '2) Feedwater Data', '3) Scaling Information', '4) System Configuration', '5) Report', and '6) Cost Analysis'. The status bar shows 'Monday, September 28, 2009' and 'Ready...'.



# Plant Design using ROSA



- **Project Information**
- Feedwater Data
- Scaling Information
- System Configuration
- Report

# ROSA – Project Description



## Project basic information

ROSA Control Panel - Project 8956

System Permeate Flow: 0.20 m<sup>3</sup>/h    System Feed Flow: 1.33 m<sup>3</sup>/h    System Recovery: 15.00%

**Project Information**

Notes: Project for XYZ Company Conventional pretreatment

Project Name: Project 8956

**Project Cases**

Notes for Current Case: Highest Fouling Factor + Highest Temperature

Case: 1    Add Case    Delete Case    Pre-stage ΔP: 0.345 bar

**Project Preferences**

Analysis By: Jane Doe     Small Commercial System

Company Name: Water Filtration 123

Balance Analysis With: NaCl

Units Set: Flow: m<sup>3</sup>/h, Pressure: bar

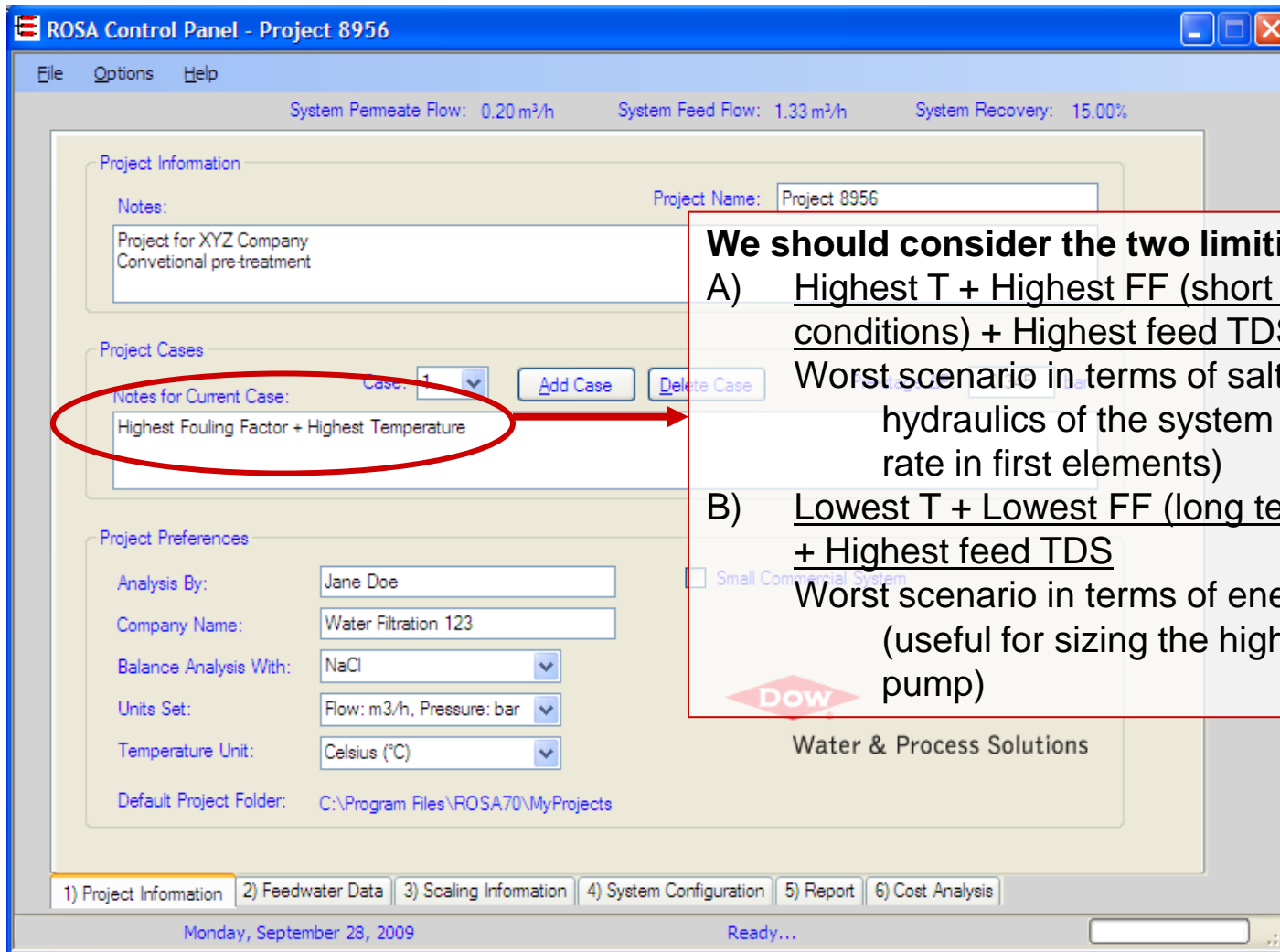
Temperature Unit: Celsius (°C)

Default Project Folder: C:\Program Files\ROSA70\MyProjects

1) Project Information    2) Feedwater Data    3) Scaling Information    4) System Configuration    5) Report    6) Cost Analysis

Monday, September 28, 2009    Ready...

# ROSA – Limiting Scenarios



**We should consider the two limiting scenarios:**

A) Highest T + Highest FF (short term conditions) + Highest feed TDS  
Worst scenario in terms of salt passage and hydraulics of the system (highest flow rate in first elements)

B) Lowest T + Lowest FF (long term conditions) + Highest feed TDS  
Worst scenario in terms of energy demand (useful for sizing the high pressure pump)

# ROSA – Flow Factors



## Flow Factor Concept:

- $FF = 1.00$  Nominal element flow performance according to specification
- $FF = 0.80$  80% of nominal element flow performance

	Flow Factor		
Membrane	Start up (expected)	+ 3 years (fouling excluded, clean membrane)	+ 3 years (expected, fouling included)
BW	1.0	0.80	0.75 – 0.65
SW	1.0	0.80	0.70 – 0.65

Long term FF (+ 3 years) depends strongly on:

- Temperature, raw water source, pre-treatment, feed pressure, etc.

# ROSA – User Defined Pre-stage Pressure Drop



ROSA Control Panel - Project 8956

System Pemeate Flow: 0.20 m<sup>3</sup>/h    System Feed Flow: 1.33 m<sup>3</sup>/h    System Recovery: 15.00%

**Project Information**

Notes: Project Name: Project 8956  
Project for XYZ Company  
Convnetional pre-treatment

**Project Cases**

Case: 1    Add Case    Delete Case    Pre-stage ΔP: 0.345 bar

Notes for Current Case: Highest Fouling Factor + Highest Temperature

**Project Preferences**

Analysis By: Jane Doe     Small Commercial S  
Company Name: Water Filtration 123  
Balance Analysis With: NaCl  
Units Set: Flow: m<sup>3</sup>/h, Pressure: bar  
Temperature Unit: Celsius (°C)  
Default Project Folder: C:\Program Files\ROSA70\MyProjects

1) Project Information    2) Feedwater Data    3) Scaling Information    4) System Configuration    5) Report    6) Cost Analysis

Monday, September 28, 2009    Ready...

Pre-stage Pressure Drop ( $\Delta P$ ) can be defined  
If the specific  $\Delta P$  is not known, leave the default value





# Plant Design using ROSA



- Project Information
- **Feedwater Data**
- Scaling Information
- System Configuration
- Report

# Addition of DOW™ Ultrafiltration Water Types



ROSA Control Panel

File Options Help

System Pemeate Flow: 0.20 gpd    System Feed Flow: 1.33 gpd    System Recovery: 15.00%

Water Type: **SELECT** Open Water Profile Library

Feed Percenta

Ions	RO Pemeate SDI < 1
Ammonium	Well Water SDI < 3
Potassium	Surface Water with Dow Ultrafiltration, SDI < 2.5
Sodium (Na)	Surface Supply SDI < 3
Magnesium	Surface Supply SDI < 5
Calcium (Ca)	Wastewater with Dow Ultrafiltration, SDI < 2.5
Strontium (Sr)	Wastewater with Generic membrane filtration, SDI < 3
Barium (Ba)	Wastewater with Conventional pretreatment, SDI < 5
Carbonate (CO3)	Seawater with Dow Ultrafiltration, SDI < 2.5
Bicarbonate (HCO3)	Seawater with Generic membrane filtration, SDI < 3
Nitrate (NO3)	Seawater with Conventional pretreatment, SDI < 5
Chloride (Cl)	
Fluoride (F)	
Sulfate (SO4)	
Silica (SiO2)	
Boron (B)	

Specify Individual Solutes

Total Dissolved Solids:  mg/l

Feed Parameters

Temperature:  °C

Flow Rate:  gpd

pH:

Charge Balance

Cations: 0.00 Add Sodium

Anions: 0.00 Add Calcium

Balance: 0.00 Adjust Cations

Adjust Anions

Adjust All Ions

System Temp: 25.0 °C    System pH: 7.60    Save Water Profile to Library

1) Project Information   2) Feedwater Data   3) Scaling Information   4) System Configuration   5) Report   6) Cost Analysis

Tuesday, November 08, 2011    Ready...



# ROSA – Introducing Feed water analysis



Choose Feed water type

Introduce the water analysis data  
 1. Check the box: Specify individual solutes  
 2. Introduce the concentrations

File Options Help

System Permeate Flow: 0.20 gpd    System Feed Flow: 1.33 gpd    System Recovery: 15.00%

Water Type: **SELECT**

Feed Percenta **SELECT**

Specify Individual Solutes

Total Dissolved Solids: 2000.0 mg/l

Feed Parameters

Temperature: 25.0 °C

Flow Rate: 1.33 gpd

pH: 7.6

Charge Balance

Cations: 0.00

Anions: 0.00

Balance: 0.00

System Temp: 25.0 °C    System pH: 7.60

Save Water Profile to Library

1) Project Information   2) Feedwater Data   3) Scaling Information   4) System Configuration   5) Report   6) Cost Analysis

Tuesday, November 08, 2011    Ready...

Ions	Surface Water with Dow Ultrafiltration, SDI < 2.5			
Ammonium	Surface Supply SDI < 3			
Potassium	Surface Supply SDI < 5			
Sodium (Na)	Wastewater with Dow Ultrafiltration, SDI < 2.5			
Magnesium	Wastewater with Generic membrane filtration, SDI < 3			
Calcium (Ca)	Wastewater with Conventional pretreatment, SDI < 5			
Strontium (Sr)	0	0.000	0.000	0.00
Barium (Ba)	0	0.000	0.000	0.00
Carbonate (CO3)	0	0.000	0.000	0.00
Bicarbonate (HCO3)	0	0.000	0.000	0.00
Nitrate (NO3)	0	0.000	0.000	0.00
Chloride (Cl)	1213.25	1711.069	34.221	1213.25
Fluoride (F)	0	0.000	0.000	0.00
Sulfate (SO4)	0	0.000	0.000	0.00
Silica (SiO2)	0	n.a.	n.a.	0.00
Boron (B)	0	n.a.	n.a.	n.a.

Introduce the T and pH

Cations and Anions should be balanced



# Choosing feedwater type



Feed water type	Description
RO Permeate SDI<1	Very-low-salinity, high-purity waters (HPW) coming from the first RO systems (double-pass RO system) or the polishing stage in ultrapure water (UPW) systems with TDS up to 50 mg/L.
Well Water SDI<3	Water from a ground source that has been accessed via well. Usually, has low fouling potential.
Surface Water with Dow Ultrafiltration SDI<2.5	Water from rivers, river estuaries and lakes. In most cases it has high TSS, NOM, BOD and colloids. Frequently, surface water quality varies seasonally.
Surface Supply SDI<3	
Surface Supply SDI<5	
Wastewater with Dow Ultrafiltration SDI<2.5	Industrial and municipal wastewaters have a wide variety of organic and inorganic constituents. Some types of organic components may adversely affect RO/NF membranes, inducing severe flow loss and/or membrane degradation (organic fouling).
Wastewater with Generic Membrane Filtration SDI<3	
Wastewater with Conventional Pretreatment SDI<5	
Seawater with Dow Ultrafiltration SDI<2.5	Seawater Dow Ultrafiltration as a pre-treatment
Seawater with Generic Membrane Filtration SDI<3	Well -water from a beach well with any type of pre-treatment Seawater any with Generic Microfiltration/Ultrafiltration as a pre-treatment
Seawater (Open Intake) SDI<5	Open intake seawater with conventional pre-treatment

# ROSA – Saving the Water Profile



ROSA Control Panel - Project 8956

System Permeate Flow: 0.20 m<sup>3</sup>/h    System Feed Flow: 1.33 m<sup>3</sup>/h    System Recovery: 15.00%

Water Type: Well Water SDI < 3

Feed Percentage: 100.0 (%)    Feed Number: 1    Feed Streams: 1

**Open Water Profile Library**

Ions	mg/l	ppm CaCO <sub>3</sub>	meq/l	Total Conc.(mg/l)
Ammonium (NH <sub>4</sub> )	0	0.000	0.000	0.00
Potassium (K)	0.97	1.240	0.025	0.97
Sodium (Na)	328.65	714.767	14.295	328.65
Magnesium (Mg)	7.12	29.286	0.586	7.12
Calcium (Ca)	9.55	23.827	0.477	9.55
Strontium (Sr)	10	11.413	0.228	10.00
Barium (Ba)	0.14	0.102	0.002	0.14
Carbonate (CO <sub>3</sub> )	0.239	0.399	0.008	0.24
Bicarbonate (HCO <sub>3</sub> )	869.76	2.137	0.043	869.76
Nitrate (NO <sub>3</sub> )	2.65	0.526	0.011	2.65
Chloride (Cl)	34.29	0.011	0.20	34.29
Fluoride (F)	0.2	0.526	0.011	0.20
Sulfate (SO <sub>4</sub> )	15.74	16.396	0.328	15.74
Silica (SiO <sub>2</sub> )	10	n.a.	n.a.	10.00
Boron (B)	0.154	n.a.	n.a.	0.154

Total Dissolved Solids: 1290.190 mg/l

Temperature: 20.00 °C    Flow Rate: 1.33 m<sup>3</sup>/h    pH: 6.52

System Temp: 20.0 °C    System pH: 7.60

**Save Water Profile to Library**

Note: Any changes in raw feedwater composition will affect scaling calculations. Please review scaling calculations.

1) Project Information    2) Feedwater Data    3) Scaling Information    4) System Configuration    5) Report    6) Cost Analysis

Tuesday, September 29, 2009    Ready...

Water Profile Library

Select Water Profile:

Profile Name: Example 1

Ammonium (NH<sub>4</sub>): 0.00 mg/l    pH: 6.52

Potassium (K): 0.97 mg/l    Temperature: 20.00 °C

Sodium (Na): 328.65 mg/l    68.00 °F

Magnesium (Mg): 7.12 mg/l

Calcium (Ca): 9.55 mg/l

Strontium (Sr): 10.00 mg/l

Barium (Ba): 0.14 mg/l

Carbonate (CO<sub>3</sub>): 0.24 mg/l

Bicarbonate (HCO<sub>3</sub>): 869.76 mg/l

Nitrate (NO<sub>3</sub>): 2.65 mg/l

Chloride (Cl): 34.29 mg/l

Fluoride (F): 0.20 mg/l

Sulfate (SO<sub>4</sub>): 15.74 mg/l

Silica (SiO<sub>2</sub>): 10.00 mg/l

Boron (H<sub>3</sub>BO<sub>3</sub>): 0.88 mg/l

**Add to Library**

Delete from Library

Close and copy to Feed

Close

Previous water profiles can be loaded

Current water profile can be added to the library

# Plant Design using ROSA



- Project Information
- Feedwater Data
- **Scaling Information**
- System Configuration
- Report

# ROSA – Scaling Information



ROSA Control Panel - Project 8956

System Pemeate Flow: 0.20 m<sup>3</sup>/h    System Feed Flow: 1.33 m<sup>3</sup>/h    System Recovery: 15.00%

File    Options    Help

Scaling Calculations Options

No chemicals added

User-adjusted pH

Ion-exchange softening

Ion-exchange Leakage

Ca Leakage:  (mg/L)

Mg Leakage:  (mg/L)

Antiscalants are required. Consult your antiscalant manufacturer for dosing and maximum allowable system recovery.

	Feed	Adj. Feed	Concentrate
pH	6.52	6.52	6.59
LSI	-1.290	-1.290	-1.085
Stiff & Davis Index	-0.821	-0.821	-0.675
TDS (mg/l)	1,290	1,290	1,518
Ionic Strength (molal)	0.016	0.016	0.019
HCO <sub>3</sub> (mg/l)	869.760	869.760	1023.247
CO <sub>2</sub> (mg/l)	345.534	345.534	345.534
CO <sub>3</sub> (mg/l)	0.239	0.239	0.282
CaSO <sub>4</sub> (% Saturation)	0.034	0.034	0.044
BaSO <sub>4</sub> (% Saturation)	72.67	72.67	100.58
SrSO <sub>4</sub> (% Saturation)	3.17	3.17	3.82
CaF <sub>2</sub> (% Saturation)	0.051	0.051	0.083
SiO <sub>2</sub> (% Saturation)	8.20	8.20	9.73
Mg(OH) <sub>2</sub> (% Saturation)	0.00000	0.00000	0.00000

Recovery and Temperature

Recovery:  (%)

Temperature:  °C

Use original feed

Use adjusted feed

User-adjusted pH

Dosing Chemical:

pH:

Concentrate LSI:

1) Project Information    2) Feedwater Data    3) Scaling Information    4) System Configuration    5) Report    6) Cost Analysis

Tuesday, September 29, 2009    Ready...

# Plant Design using ROSA



- Project Information
- Feedwater Data
- Scaling Information
- **System Configuration**
- Report



# ROSA - Introduction of known data



## The Flow Calculator

- New way to enter project input
- Flows and recoveries of both passes can be defined at the same time
- The quantity of permeate blending or permeate split can be determined at the same time

A screenshot of the "Flow Calculator" software window. The window has a blue title bar with the text "Flow Calculator" and standard window control buttons. The main area is divided into two sections: "Pass 1" and "Pass 2".  
**Pass 1**  
This section contains five input fields with labels above them: "Feed Flow", "Recovery", "Permeate Flow", "Flux", and "Permeate Split".  
- "Feed Flow": 93.72 m³/h, with a "Specify" checkbox below it.  
- "Recovery": 92.83 %, with a "Specify" checkbox below it.  
- "Permeate Flow": 87.00 m³/h, with a "Specify" checkbox below it.  
- "Flux": 27.87 lmh.  
- "Permeate Split": 0.00 %, with a "Blend" checkbox and an empty "m³/h" input field below it.  
Below these fields is the instruction: "Specify two of the three parameters."  
**Pass 2**  
This section contains five input fields with labels above them: "Feed Flow", "Recovery", "Permeate Flow", "Flux", and "Final Permeate".  
- "Feed Flow": 0.00 m³/h, with a "Specify" checkbox below it.  
- "Recovery": 0.00 %, with a "Specify" checkbox below it.  
- "Permeate Flow": 0.00 m³/h, with a "Specify" checkbox below it.  
- "Flux": 0.00 lmh.  
- "Final Permeate": an empty "m³/h" input field.  
At the bottom of the window are five buttons: "Help", "Recalculate", "Reset", "Cancel", and "Accept Changes and Close".

# ROSA - Introduction of known data



ROSA Control Panel - Project 8956

System Permeate Flow: 87.00 m<sup>3</sup>/h System Feed Flow: 93.72 m<sup>3</sup>/h

No. Passes: 1 Current Pass: 1 Dosing Chemical: None Adjusted pH: None

Configuration for Pass 1

Stages in Pass: 2 Permeate Flow: 87.00 m<sup>3</sup>/h Recovery: 92.83 % Feed Flow: 93.72 m<sup>3</sup>/h

Fouling Factor: 0.95

Operating Temp: 20.0 °C

Flow Calculator

Pass 1

Feed Flow	Recovery	Permeate Flow
93.72 m <sup>3</sup> /h	92.83 %	87.00 m <sup>3</sup> /h

Specify  Specify  Specify

Specify two of the three parameters.

Blend  Blend m<sup>3</sup>/h

Pass 2

Feed Flow	Recovery	Permeate Flow	Flux	Final Permeate
0.00 m <sup>3</sup> /h	0.00 %	0.00 m <sup>3</sup> /h	0.00 lmh	m <sup>3</sup> /h

Specify  Specify

Buttons: Help Recalculate Reset Cancel Accept Changes and Close

**To introduce the Flow and Recovery data:**

1. Double click on any of the boxes: Permeate Flow, Recovery, Feed Flow or Permeate Flux
2. Pop-up window (Flow Calculator) will appear
3. Specify two parameters to be introduced by checking the Specify box
4. Introduce the data
5. Click on Recalculate
6. Click on Accept Changes and Close

# ROSA – Membrane Element Selection



**ROSA Control Panel - Project 8956**

System Pemeate Flow: 0.20 m³/h    System Feed Flow: 1.33 m³/h    System Recovery: 15.00%

No. Passes:  1    Current Pass:  1

Dosing Chemical: None     No Degasification

Adjusted pH: None     % Carbon Removal: None

CO2 Pressure (atm)

**Configuration for Pass 1**

Stages in Pass: 1    Pemeate Flow: 0.20 m³/h    Recirculation Loops

Fouling Factor: 0.85    Recovery: 15.00 %     Blend Pemeate

Operating Temp: 20.0 °C    Feed Flow: 1.33 m³/h     Pass 1 Conc to Pass 1 Feed

Pemeate Flux: 25.33 lmh     Pass 2 Conc to Pass 1 Feed

**Configuration for Stage 1 in Pass 1**

Stage in Pass: Stage 1     ISD

Feed Pressure: None bar    Pump Efficiency: 80.0 %

Boost (2-pass): Calc    Back Pressure: None bar

Same back pressure for all stages

Pressure vessels in each stage: 1

Elements in each vessel: 1

Total elements in stage: 1

Products: SW30HRLE-4040   

Use the

1) Project Inform...    3) Scaling Information...    4) System Configuration    5) Report    6) Cost Analysis

09    Ready...

**System Configuration Diagram:**

# Multistage systems: Staging ratio calculation



- Typical staging ratio:
- 1.5 sea water systems with 6-element vessels
  - 2 brackish water systems with 6-element vessels
  - 3 2<sup>nd</sup> pass RO systems

**Configuration for Pass 1**

No. Passes	1	Current Pass	1	Dosing Chemical	None
Stages in Pass	2	Pemate Flow	92.98 m <sup>3</sup> /h	Recovery	87.00 %
Fouling Factor	0.95	Feed Flow	106.87 m <sup>3</sup> /h	Pemate Flux	29.79 l/mh
Operating Temp	20.0 °C	<b>Recirculation Loops</b>			
		<input type="checkbox"/> Blend Pemate			
		<input type="checkbox"/> Pass 1 Conc to Pass 1 Feed	None		
		<input type="checkbox"/> Pass 2 Conc to Pass 1 Feed	None		Max

**Configuration for Stage 1 in Pass 1**

Stage in Pass	Stage 1	ISD	<input type="checkbox"/>
Feed Pressure	None	Pump Efficiency	80.0 %
Boost (2-pass)	Calc	Pressure vessels in each stage	8
Back Pressure	None	Elements in each vessel	7
<input checked="" type="checkbox"/> Same back pressure for all stages		Total elements in stage	56
Products	LE-400		
<input checked="" type="checkbox"/> Use the same element in the pass			

**System Configuration**

The active stage/Pass is highlighted. Click on the system configuration to move from one stage to another

# Number of Elements per Pressure Vessel Selection



**ROSA Control Panel - Project 8956**

System Pemeate Flow: 92.98 m<sup>3</sup>/h    System Feed Flow: 106.87 m<sup>3</sup>/h    System Recovery: 87.00%

No. Passes:  1    2    Current Pass:  1    2

Dosing Chemical: None     No Degasification  
Adjusted pH: None     % Carbon Removal None  
 CO2 Pressure (atm)

**Configuration for Pass 1**

Stages in Pass: 2    Pemeate Flow: 92.98 m<sup>3</sup>/h    Recirculation Loops  
Fouling Factor: 0.95    Recovery: 87.00 %     Blend Pemeate  
Operating Temp: 20.0 °C    Feed Flow: 106.87 m<sup>3</sup>/h     Pass 1 Conc to Pass 1 Feed  
Pemeate Flux: 29.79 l/mh     Pass 2 Conc to Pass 1 Feed    Max

**Configuration for Stage 1 in Pass 1**

Stage in Pass: Stage 1     ISD ?  
Feed Pressure: None bar    Pump Efficiency: 80.0 %  
Boost (2-pass): Calc  
Back Pressure: None bar  
 Same back pressure for all stages  
Pressure vessels in each stage: 8  
Elements in each vessel: 7  
Total elements in stage: 56  
Products: LE-400    Specs  
 Use the same element in the pass

**System Configuration**

1) Project Information   2) Feedwater Data   3) Scaling Information   4) System Configuration   5) Report   6) Cost Analysis

Tuesday, September 29, 2009    Ready...

# Number of Elements selection: Average system flux



Select the design flux (f) based on

- pilot data
- customer experience
- typical design fluxes according to the feed source found in [System Design Guidelines](#)
- CAPEX or OPEX focus

$$N_E = \frac{Q_P}{f \cdot S_E}$$

$N_E$ : number of elements

$Q_P$ : design permeate flow rate of system

f: flux

$S_E$ : active membrane area of the selected element

# Plant Design using ROSA



- Project Information
- Feedwater Data
- Scaling Information
- System Configuration
- **Report**

# Example - ROSA Report



**Project Information:** Project for XYZ Company Conventional pre-treatment

**Case-specific:** Highest Fouling Factor + Highest Temperature

## System Details

Feed Flow to Stage 1	106.87 m <sup>3</sup> /h	Pass 1 Permeate Flow	92.97 m <sup>3</sup> /h	Osmotic Pressure:	
Raw Water Flow to System	106.87 m <sup>3</sup> /h	Pass 1 Recovery	86.99 %	Feed	0.71 bar
Feed Pressure	11.37 bar	Feed Temperature	20.0 C	Concentrate	5.12 bar
Fouling Factor	0.95	Feed TDS	1290.21 mg/l	Average	2.91 bar
Chem. Dose	None	Number of Elements	84	Average NDP	7.13 bar
Total Active Area	3121.44 M <sup>2</sup>	Average Pass 1 Flux	29.78 lmh	Power	42.20 kW
Water Classification: Well Water SDI < 3				Specific Energy	0.45 kWh/m <sup>3</sup>

Stage	Element	#PV	#Ele	Feed Flow (m <sup>3</sup> /h)	Feed Press (bar)	Recirc Flow (m <sup>3</sup> /h)	Conc Flow (m <sup>3</sup> /h)	Conc Press (bar)	Perm Flow (m <sup>3</sup> /h)	Avg Flux (lmh)	Perm Press (bar)	Boost Press (bar)	Perm TDS (mg/l)
1	LE-400	8	7	106.87	11.02	0.00	32.83	8.90	74.05	35.58	0.00	0.00	21.28
2	LE-400	4	7	32.83	8.56	0.00	13.91	7.44	18.92	18.18	0.00	0.00	105.54

### Pass Streams (mg/l as Ion)

Name	Feed	Adjusted Feed	Concentrate		Permeate		
			Stage 1	Stage 2	Stage 1	Stage 2	Total
			NH4	0.00	0.00	0.00	0.00
K	0.97	0.97	2.83	5.82	0.14	0.64	0.24
Na	328.65	328.67	1058.55	2461.66	5.12	27.05	9.58
Mg	7.12	7.12	23.04	53.96	0.06	0.31	0.11
Ca	9.55	9.55	30.91	72.40	0.08	0.41	0.15
Sr	10.00	10.00	32.37	75.81	0.08	0.43	0.16
Ba	0.14	0.14	0.45	1.06	0.00	0.01	0.00
CO3	0.24	0.24	3.24	22.86	0.00	0.00	0.00
HCO3	869.76	869.76	2796.09	6471.17	14.44	71.78	25.88
NO3	2.65	2.65	7.90	16.65	0.32	1.47	0.56
Cl	34.29	34.29	111.04	260.07	0.27	1.48	0.51
F	0.20	0.20	0.64	1.50	0.00	0.02	0.01
SO4	15.74	15.74	51.07	119.96	0.08	0.42	0.15
SiO2	10.00	10.00	32.36	75.85	0.09	0.38	0.15
Boron	0.15	0.15	0.27	0.36	0.10	0.20	0.12
CO2	345.56	345.56	346.91	355.53	345.17	348.66	346.04
TDS	1290.19	1290.21	4152.04	9640.84	21.28	105.54	38.20
pH	N/A	N/A	N/A	N/A	N/A	N/A	N/A



# Example - ROSA Report



## Design Warnings

WARNING: Maximum recommended element permeate flow rate has been exceeded. Please change your system design to reduce the element permeate flows. (Product: LE-400, Limit: 1.44m<sup>3</sup>/h)  
 WARNING: Maximum element recovery has been exceeded. Please change your system design to reduce the element recoveries. (Product: LE-400, Limit: 19.00%)

## Solubility Warnings

Langelier Saturation Index > 0  
 Stiff & Davis Stability Index > 0  
 BaSO<sub>4</sub> (% Saturation) > 100%  
 Antiscalants may be required. Consult your antiscalant manufacturer for dosing and maximum allowable system recovery.

Designs of systems in excess of the guidelines results in a warning on the ROSA Report.

## Stage Details

Stage 1	Element	Recovery	Perm Flow (m <sup>3</sup> /h)	Perm TDS (mg/l)	Feed Flow (m <sup>3</sup> /h)	Feed TDS (mg/l)	Feed Press (bar)
	1	0.12	1.57	11.70	13.36	1290.21	11.02
	2	0.18	1.47	13.56	11.79	1460.17	10.50
	3	0.13	1.39	16.02	10.32	1666.56	10.07
	4	0.15	1.31	19.36	8.93	1923.00	9.72
	5	0.16	1.25	24.04	7.62	2251.13	9.43
	6	0.18	1.18	30.99	6.37	2686.19	9.20
	7	0.21	1.10	41.87	5.20	3286.44	9.03
Stage 2	Element	Recovery	Perm Flow (m <sup>3</sup> /h)	Perm TDS (mg/l)	Feed Flow (m <sup>3</sup> /h)	Feed TDS (mg/l)	Feed Press (bar)
	1	0.12	1.01	50.77	8.21	4152.04	8.56
	2	0.12	0.90	63.99	7.20	4724.16	8.30
	3	0.12	0.79	81.83	6.30	5386.59	8.08
	4	0.12	0.67	106.30	5.52	6141.11	7.90
	5	0.12	0.56	140.36	4.84	6977.61	7.76
	6	0.11	0.45	188.48	4.28	7869.93	7.63
	7	0.09	0.35	256.91	3.83	8774.98	7.53



# Warnings and typical solutions – For one stage systems



Design warning	Solutions
Max. element <b>permeate flow</b> exceeded	3, 5, 7, 11
The <b>concentrate flow</b> less than minimum	1, 5, 4 together with 6
The <b>feed flow</b> greater than maximum	2 unless the feed flow is fixed, 3
Maximum <b>feed pressure</b> exceeded	1, 3, 8
<b>Temperature</b> is above acceptable value	10
Max. element <b>recovery</b> exceeded: <ul style="list-style-type: none"> <li>• If the problem is encountered in front elements</li> <li>• If the problem is encountered in rear elements</li> </ul>	1, 5, 6, 11 1, 5, 6

## Solutions Guide

1	Decrease system recovery	6	Increase the number of elements per PV (keeping the same APF*)	10	Reduce Temp (recommend customer to reduce temp during pretreatment).
2	Increase system recovery	7	Decrease the number of elements per PV (keeping the same APF*)	11	Combine two element types: lower energy elements in rear positions (ISD configuration)
3	Reduce average system flux (add membranes, PV)	8	Install lower energy membranes or ISD with lower energy membranes		
4	Reduce number of PV (increasing average system flux)				
5	Enable a recirculation loop Pass 1 Conc to Pass 1 Feed (normally not used for SW appl.)				

\*APF – Average Permeate Flux  
\*\*PV=Pressure vessel

# Warnings and typical solutions – For multistage systems



Design warning	Solutions
Max. element <b>permeate flow</b> exceeded	3, (5), 6, 10, 13
The <b>concentrate flow</b> less than minimum	1, 4, (5), 6, 7, (10 and 11 only for the 1 <sup>st</sup> stage)
The <b>feed flow</b> greater than maximum in any of the stages	2, 3
Maximum <b>feed pressure</b> exceeded	1, 3, 9
<b>Temperature</b> is above acceptable value	12
Max. element <b>recovery</b> exceeded: <ul style="list-style-type: none"> <li>• If the problem is encountered in front elements (front stage/s)</li> <li>• If the problem is encountered in rear elements (rear stage/s)</li> </ul>	1, (5), 6, 7, 10, 13 1, (5), 7

1 Decrease system recovery

2 Increase system recovery

3 Increase number of PV (reducing average system flux)

4 Reduce number of PV (increasing average system flux)

5 Enable a recirculation loop: Pass 1 Conc to Pass 1 Feed (normally not used for SW appl.)

## Solutions Guide

6 Add backpressure in first and/or second stages permeate streams

7 Increase the number of elements per PV (keeping the same APF)

8 Decrease the number of elements per PV (keeping the same APF)

9 Install lower energy membranes or ISD with lower energy membranes

10 Add booster pump in first or second stage concentrate

11 Use a lower active area membrane element (keeping the same APF)

12 Reduce Temp (recommend customer to reduce temp during pretreatment).

13 Combine two element types: lower energy elements in second or third stages



# Further Help – Answer Center



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Results 31 - 45 of 207 for ROSA

#### Summary

FILMTEC Membranes - ROSA - Change report language

FILMTEC Membranes - e-mail pdf version of projection

FILMTEC Membranes - pH Adjustment in the Second Pass in ROSA

FILMTEC Membranes - EVA (Element Value Analysis)

FILMTEC Membranes - Blending in ROSA

FILMTEC Membranes - ROSA - Different Feed Water Streams

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# RO System Design Webinar Series



## Reverse Osmosis System Design Basics

**Date & Time**  
Sept 9, 2015  
1-3 pm CDT

## ROSA System Design Basics

**Date & Time**  
Sept 11, 2015  
1-3 pm CDT

## RO Webinar Series Speakers:



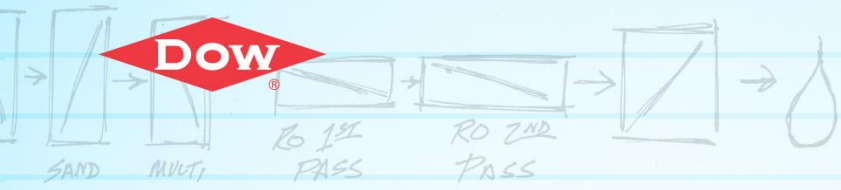
Scott Beardsley & Steven Coker  
Technical Service Specialists

## Advanced Reverse Osmosis System Design

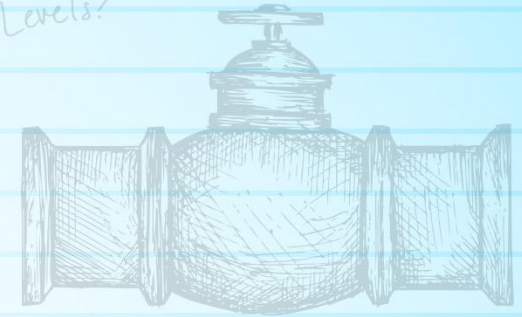
**Date & Time**  
Sept 23, 2015  
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## Advanced RO System Design with ROSA

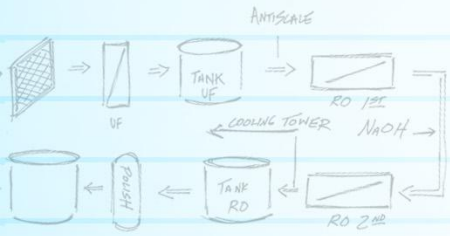
**Date & Time**  
Sept 30, 2015  
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Expected Conductivity Levels?

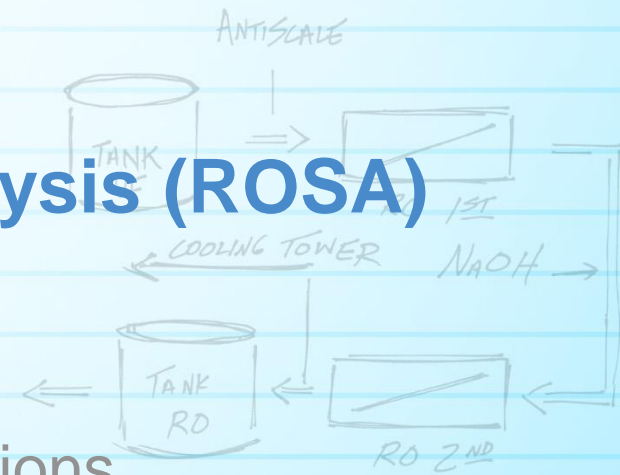


pH Break vs. Con Break - Cycle

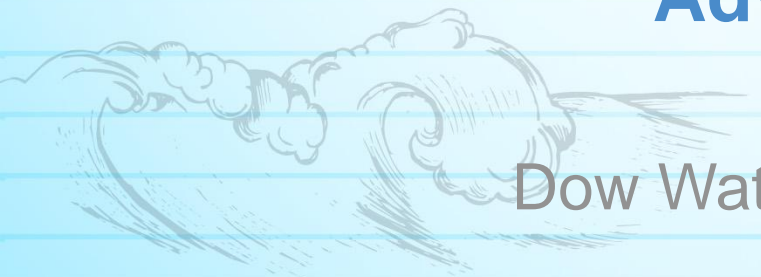


What are the standard Water Quality Guidelines?

# Reverse Osmosis System Analysis (ROSA) Advanced Design



Steven Coker  
Dow Water & Process Solutions



# RO System Design Webinar Series



## Reverse Osmosis System Design Basics

**Date & Time**  
Sept 9, 2015  
1-3 pm CDT

## ROSA System Design Basics

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Sept 11, 2015  
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Technical Service Specialists

## Advanced Reverse Osmosis System Design

**Date & Time**  
Sept 23, 2015  
1-3 pm CDT

## Advanced RO System Design with ROSA

**Date & Time**  
Sept 30, 2015  
1-3 pm CDT



# ROSA – Advanced RO Plant Design



- Review of a few ROSA basics
- ROSA procedures for Advanced RO Designs
- Temperature History Effect - SWRO
- Batch Processor Option
- System Optimization – Design Warning Mitigation

# ROSA Basics: Name it and Save it!



ROSA Control Panel - Project 2015 - 275

File Options Help

System Pemeate Flow: 0.20 gpm    System Feed Flow: 1.33 gpm    System Recovery: 15.00%

Project Information

Notes:

Project Cases

Notes for Current Case: Case: 1    Pre-stage ΔP: 5.000 psig

Project Preferences

Analysis By:   Small Commercial System

Company Name:

Balance Analysis With:

Units Set:

Temperature Unit:

Default Project Folder: C:\Users\u140556\Documents\ROSA Projects

The logo for Dow Water & Process Solutions, featuring the word "DOW" in white on a red diamond shape, with "Water & Process Solutions" in black text below it.

1) Project Information | 2) Feedwater Data | 3) Scaling Information | 4) System Configuration | 5) Report | 6) Cost Analysis

Sunday, September 27, 2015    Ready...



# ROSA Basics: Multi-Case File



ROSA Control Panel - Project 2015 - 275

File Options Help

System Pervate Flow: 0.20 gpm    System Feed Flow: 1.33 gpm    System Recovery: 15.00%

Project Information

Notes: Project Name: Project 2015 - 275

Project 2015-275  
Preliminary Design

Project Cases

Case: 8    Add Case    Delete Case    Manage    Pre-stage ΔP: 5.000 psig

Notes for Current Case:  
Year 3 - Maximum Temperature - 85% Recovery

Project Preferences

Analysis By: John Doe     Small Commercial System

Company Name: The Good Guys

Balance Analysis With: NaCl

Units Set: Flow: gpm, Pressure: psig

Temperature Unit: Celsius (°C)

Default Project Folder: C:\Users\u140556\Documents\ROSA Projects

1) Project Information    2) Feedwater Data    3) Scaling Information    4) System Configuration    5) Report    6) Cost Analysis

Sunday, September 27, 2015    Ready...



# ROSA Basics: Manage Case Order



The screenshot shows the ROSA Control Panel interface. The main window is titled "ROSA Control Panel - Project 2015 - 275". It has a menu bar with "File", "Options", and "Help". Below the menu bar, there are three status indicators: "System Pemeate Flow: 0.20 gpm", "System Feed Flow: 1.33 gpm", and "System Recovery: 15.00%".

The central part of the interface is a "Case Manager" window. It contains a table with the following data:

Case No.	Case Note
1	Year 0 - Min T
2	Year 0 - Max T
3	Year 1 - Min T
4	Year 1 - Max T
5	Year 2 - Min T
6	Year 2 - Max T
7	Year 3 - Min T
8	Year 3 - Max T

To the right of the table are two large blue arrows, one pointing up and one pointing down, used for reordering cases. Below the table is a "Close" button. On the right side of the Case Manager window, there is a vertical slider and a list of radio buttons labeled 1 through 8, with radio button 8 selected.

At the bottom of the Case Manager window, it says "Default Project Folder: C:\Users\u140556\Documents\ROSA Projects".

The bottom of the ROSA Control Panel window has a navigation bar with tabs: "1) Project Information", "2) Feedwater Data", "3) Scaling Information", "4) System Configuration", "5) Report", and "6) Cost Analysis". The status bar at the very bottom shows "Sunday, September 27, 2015" and "Ready...".

# Overview of Using ROSA



- Enter project information
- Enter feed water data
- If needed, enter pH modification for scale control
- Enter system configuration and select membranes
- Run report
- Evaluate report and iterate to optimize if needed

# Advanced RO System Design Options



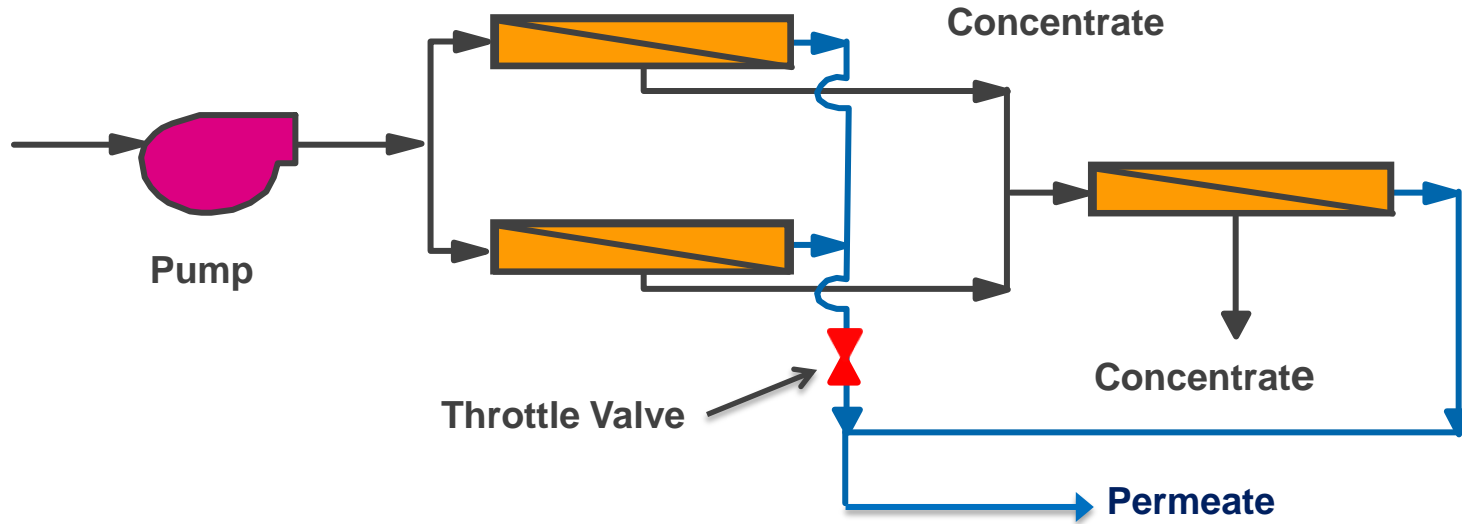
## Managing Flux Balance

- Stage 1 permeate backpressure
- Stage 2 boost pump
- Multi-element hybrid array
- Internally Staged Design (ISD) array

## Managing Permeate Quality

- RO with feed water/permeate blending
- 2 pass RO system
- 2 pass RO system w/ partial 2<sup>nd</sup> pass
- 2 pass RO system w/ permeate split design

# Balancing Flux with Stage 1 Permeate Pressure





# Stage 1 Permeate Back Pressure



1. Activate Stage 1 by clicking on it
2. Uncheck "Same Back Pressure..."
3. Enter stage 1 back pressure

The screenshot shows the ROSA Control Panel - Flux Balancing software interface. The main configuration area is titled "Configuration for Stage 1 in Pass 1". It includes the following settings:

- Stage in Pass: Stage 1
- Feed Pressure: None psig
- Boost (2-pass): Calc
- Back Pressure: 53.00 psig
- Same back pressure for all stages
- Pressure vessels in each stage: 16
- Elements in each vessel: 7
- Total elements in stage: 112
- Products: XLE-440
- Use the same element in the pass

The "System Configuration" section on the right shows a schematic diagram of a membrane system. A red arrow labeled "1" points to the feed inlet of the first membrane stage. A red arrow labeled "2" points to the "Same back pressure for all stages" checkbox. A red arrow labeled "3" points to the "Back Pressure" field.

At the bottom of the interface, there is a navigation bar with tabs: 1) Project Information, 2) Feedwater Data, 3) Scaling Information, 4) System Configuration, 5) Report, 6) Cost Analysis. The status bar at the bottom indicates the date "Monday, September 28, 2015" and the message "Opened project 'Flux Balancing'".



# Stage 1 Permeate Back Pressure - Report



## System Details

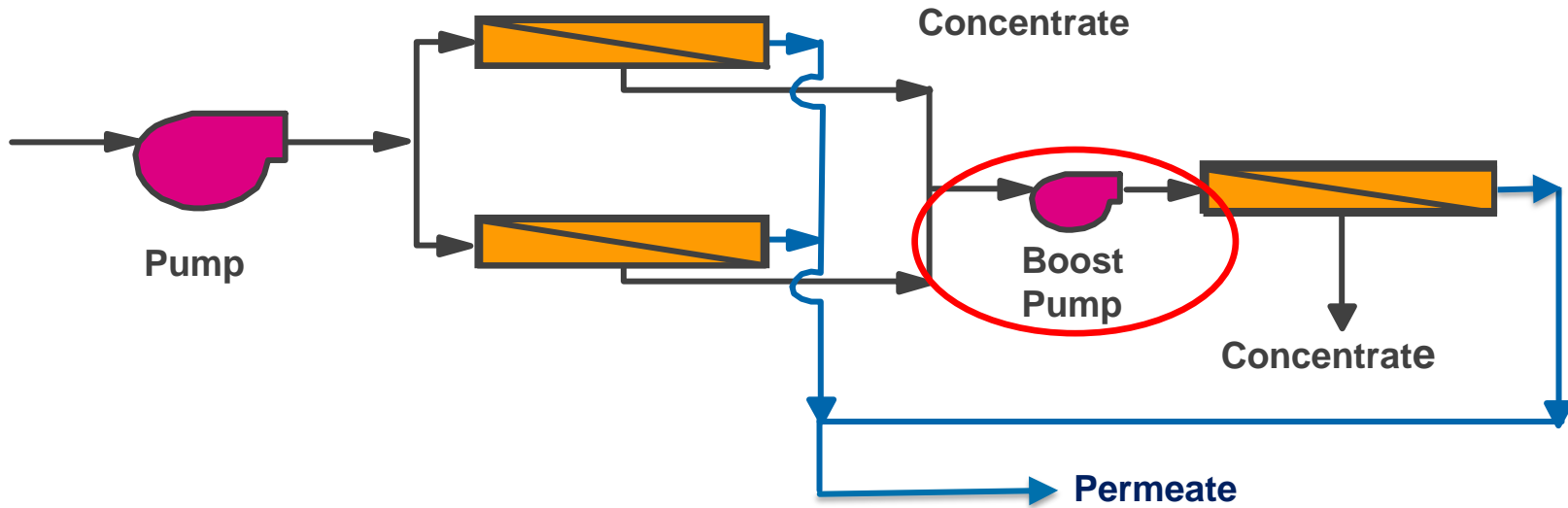
Feed Flow to Stage 1	867.50 gpm	Pass 1 Permeate Flow	693.92 gpm	Osmotic Pressure:	
Raw Water Flow to System	867.50 gpm	Pass 1 Recovery	79.99 %	Feed	19.18 psig
Feed Pressure	148.04 psig	Feed Temperature	25.0 C	Concentrate	87.37 psig
Flow Factor	1.00	Feed TDS	2001.83 mg/l	Average	53.28 psig
Chem. Dose	None	Number of Elements	168	Average NDP	87.19 psig
Total Active Area	73920.00 ft <sup>2</sup>	Average Pass 1 Flux	13.52 gfd	Power	69.84 kW
Water Classification: Well Water SDI < 3				Specific Energy	1.68 kWh/kgal

Stage	Element	#PV	#Ele	Feed Flow (gpm)	Feed Press (psig)	Recirc Flow (gpm)	Conc Flow (gpm)	Conc Press (psig)	Perm Flow (gpm)	Avg Flux (gfd)	Perm Press (psig)	Boost Press (psig)	Perm TDS (mg/l)
1	XLE-440	16	7	867.50	148.04	0.00	379.01	123.07	488.49	14.27	53.00	0.00	63.76
2	XLE-440	8	7	379.01	123.07	0.00	173.58	102.92	205.44	12.01	0.00	0.00	172.89

Name	Pass Streams (mg/l as Ion)						
	Feed	Adjusted Feed	Concentrate		Permeate		Total
			Stage 1	Stage 2	Stage 1	Stage 2	
NH4+ + NH3	0.09	0.11	0.26	0.52	0.03	0.04	0.03
K	10.00	10.00	22.36	47.50	0.41	1.12	0.62
Na	443.00	443.01	991.30	2108.09	17.60	47.72	26.51
Mg	70.00	70.00	158.32	340.96	1.47	4.01	2.22
Ca	160.00	160.00	361.97	779.73	3.29	9.01	4.98
Sr	1.80	1.80	4.07	8.77	0.04	0.10	0.06
Ba	0.01	0.01	0.02	0.05	0.00	0.00	0.00
CO3	10.43	10.43	25.51	59.70	0.01	0.01	0.01

- Stage 1 permeate back pressure is shown in System Details in ROSA report
- Impact of back pressure is seen by comparing stage-wise flux values

# Balancing Flux with Stage 2 Boost Pressure



Boost pump can be driven electrically or by energy recovery device.

# Adding Stage 2 Boost Pump



1. Activate Stage 2 by clicking on it
2. Enter stage 2 boost pressure

# Stage 2 Boost Pressure - Report



## System Details

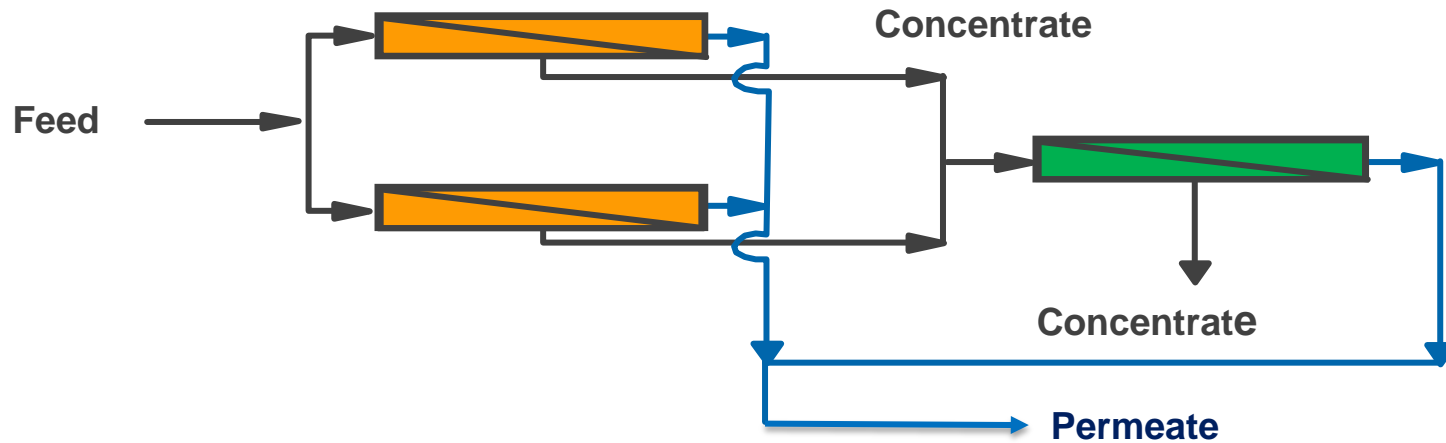
Feed Flow to Stage 1	867.50 gpm	Pass 1 Permeate Flow	694.04 gpm	Osmotic Pressure:	
Raw Water Flow to System	867.50 gpm	Pass 1 Recovery	80.01 %	Feed	19.18 psig
Feed Pressure	102.67 psig	Feed Temperature	25.0 C	Concentrate	87.47 psig
Flow Factor	0.85	Feed TDS	2001.83 mg/l	Average	53.33 psig
Chem. Dose	None	Number of Elements	168	Average NDP	59.25 psig
Total Active Area	73920.00 ft <sup>2</sup>	Average Pass 1 Flux	13.52 gfd	Power	59.44 kW
Water Classification: Well Water SDI < 3				Specific Energy	1.43 kWh/kgal

Stage	Element	#PV	#Ele	Feed Flow (gpm)	Feed Press (psig)	Recirc Flow (gpm)	Conc Flow (gpm)	Conc Press (psig)	Perm Flow (gpm)	Avg Flux (gfd)	Perm Press (psig)	Boost Press (psig)	Perm TDS (mg/l)
1	XLE-440	16	7	867.50	102.67	0.00	381.55	77.30	485.95	14.20	0.00	0.00	63.32
2	XLE-440	8	7	381.55	130.30	0.00	173.46	109.70	208.10	12.16	0.00	53.00	168.90

Pass Streams (mg/l as Ion)								
Name	Feed	Adjusted Feed	Concentrate		Permeate			Total
			Stage 1	Stage 2	Stage 1	Stage 2		
NH4+ + NH3	0.09	0.11	0.26	0.52	0.03	0.04	0.03	
K	10.00	10.00	22.22	47.56	0.41	1.09	0.61	
Na	443.00	443.01	984.98	2110.73	17.47	46.62	26.21	
Mg	70.00	70.00	157.29	341.30	1.46	3.92	2.20	
Ca	160.00	160.00	359.62	780.50	3.27	8.80	4.92	
Sr	1.80	1.80	4.05	8.78	0.04	0.10	0.06	
Ba	0.01	0.01	0.02	0.05	0.00	0.00	0.00	
CO3	10.43	10.43	25.33	59.77	0.01	0.01	0.01	
HCO3	200.00	200.00	445.20	954.80	5.31	13.85	7.87	
NO3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Cl	934.40	934.40	2082.71	4476.28	32.78	87.59	49.21	
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	



# Multi-Element Hybrid Array





# Multi-Element Hybrid Array - ROSA



ROSA Control Panel - Advanced ROSA

File Options Help

System Permeate Flow: 694.12 gpm System Feed Flow: 836.25 gpm System Recovery: 83.00%

No. Passes Current Pass Dosing Chemical: None No Degasification

1. Activate stage 1 by clicking on it  
2. Uncheck "Use same element in the pass"  
3. Select element type for stage 1

Permeate Flux: 13.22 gfd

Configuration for Stage 1 in Pass 1

Stage in Pass: Stage 1

Feed Pressure: None psig

Boost (2-pass): Calc

Back Pressure: None psig

Same back pressure for all stages

Pressure vessels in each stage: 18

Elements in each vessel: 7

total elements in stage: 126

Products: NF90-400/34i

Use the same element in the pass

System Configuration

1 Project Information 2 Feedwater Data 3 Scaling Information 4 System Configuration 5 Report 6 Cost Analysis

Tuesday, September 29, 2015 Ready...

# Multi-Element Hybrid Array - ROSA



ROSA Control Panel - Advanced ROSA

File Options Help

System Pervate Flow: 694.12 gpm System Feed Flow: 836.25 gpm System Recovery: 83.00%

No. Passes Current Pass Dosing Chemical: None

**1. Activate stage 2 by clicking on it**  
**2. Select element type for stage 2**

Flow Factor: 1.00 Feed Flow: 836.25 gpm  
Operating Temp: 20.0 °C Pervate Flux: 13.22 gfd

Configuration for Stage 2 in Pass 1

Stage in Pass: Stage 2

Boost: None psig

Boost (2-pass): Calc

Back Pressure: None psig

Same back pressure for all stages

Pressure vessels in each stage: 9

Elements in each vessel: 7

**2** Total elements in stage: 63

Products: NF270-400/34i

System Configuration

1

1) Project Information | 2) Feedwater Data | 3) Scaling Information | 4) System Configuration | 5) Report | 6) Cost Analysis

Tuesday, September 29, 2015 Ready...

# Using Multiple Elements in an Array



Stage	Element	#PV	#Ele	Feed Flow (gpm)	Feed Press (psig)	Recirc Flow (gpm)	Conc Flow (gpm)	Conc Press (psig)	Perm Flow (gpm)	Avg Flux (gfd)	Perm Press (psig)	Boost Press (psig)	Perm TDS (mg/l)
1	NF90-400/34i	18	7	836.25	54.23	0.00	359.94	43.50	476.31	13.61	0.00	0.00	36.26
2	NF270-400/34i	9	7	359.94	43.50	0.00	142.13	32.84	217.81	12.45	0.00	0.00	805.39

Pass Streams (mg/l as Ion)								
Name	Feed	Adjusted Feed	Concentrate		Permeate			Total
			Stage 1	Stage 2	Stage 1	Stage 2		
NH4+ + NH3	0.11	0.11	0.24	0.37	0.02	0.14	0.06	
K	10.00	10.00	21.96	31.50	0.96	15.73	5.60	
Na	113.37	113.37	250.38	355.41	9.83	181.84	62.81	
Mg	25.00	25.00	57.16	115.65	0.70	18.99	6.44	
Ca	55.00	55.00	125.80	230.16	1.50	57.70	19.13	
Sr	1.80	1.80	4.12	7.77	0.05	1.73	0.58	
Ba	0.01	0.01	0.02	0.04	0.01	0.01	0.00	
CO3	1.10	1.10	4.29	9.92	0.00	1.18	0.13	
HCO3	140.00	140.00	314.84	560.31	5.25	153.54	52.24	
NO3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Cl	195.37	195.42	433.51	585.58	15.49	334.28	115.53	
F	8.00	8.00	17.52	23.48	0.81	13.62	4.83	
SO4	85.00	85.00	196.05	489.81	1.08	4.37	2.11	
SiO2	12.00	12.00	27.13	34.61	0.57	22.25	7.37	
Boron	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
CO2	1.89	1.89	2.87	4.56	2.07	2.16	1.94	
TDS	646.76	646.82	1453.03	2444.65	36.26	805.39	277.83	
pH	8.00	8.00	8.13	8.13	6.62	7.98	7.60	

Increased TH

Increased Alk

Increased TDS

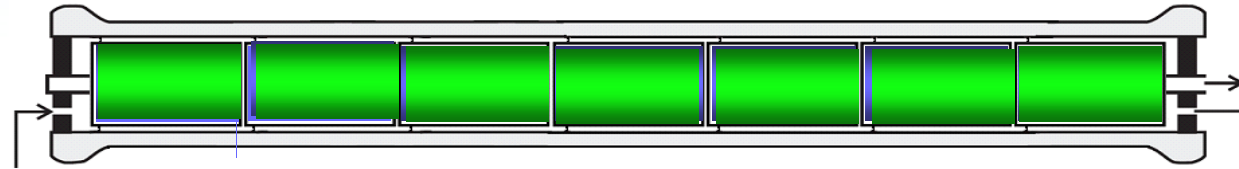
## Design Warnings

-None-

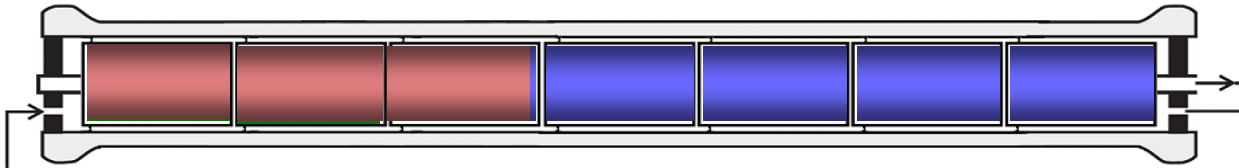
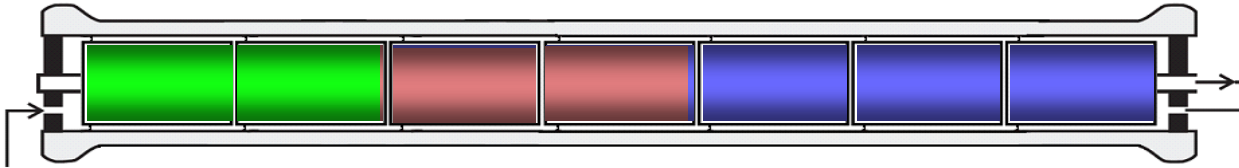
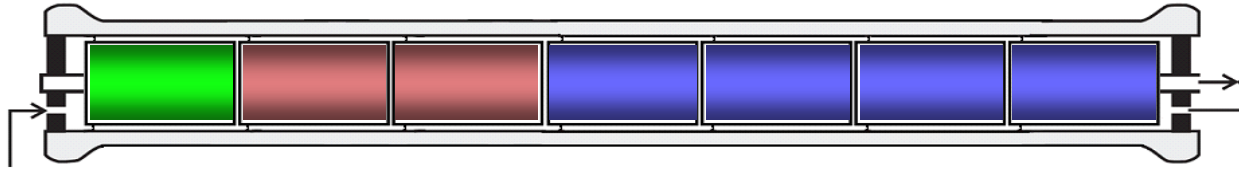
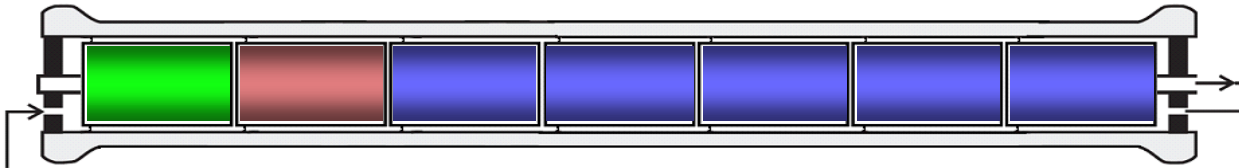




# SWRO Internally Staged Array



Examples of Potential FILMTEC™ ISD Element Loading Options



7,500 gpd



9,000 gpd



11,000 gpd

# Internally Staged Design – Stage 1



ROSA Control Panel - Advanced ROSA

File Options Help

System Pemeate Flow: 693.99 gpm System Feed Flow: 1542.16 gpm System Recovery: 45.00%

No. Passes: 1 (selected) 2  
Current Pass: 1 (selected) 2

Dosing Chemical: \_\_\_\_\_  
Adjusted pH: \_\_\_\_\_

Configuration for Pass 1

**2** Stages in Pass: 2

Flow Factor: 1.00  
Operating Temp: 24.0 °C

Pemeate Flow: \_\_\_\_\_  
Recovery: \_\_\_\_\_  
Feed Flow: \_\_\_\_\_  
Pemeate Flux: \_\_\_\_\_

Configuration for Stage 1 in Pass 1

Stage in Pass: Stage 1  ISD ?

Feed Pressure: None psig Pump Efficiency: 80.0 %

Boost (2-pass): Calc

Back Pressure: None psig

Same back pressure for all stages

Pressure vessels in each stage: 30

**3** Elements in each vessel: 3

Total elements in stage: 90

**5** Products: SW30XHR-440i Specs

**4**  Use the same element in the pass

1) Project Information | 2) Feedwater Data | 3) Scaling Information | 4) System Configuration | 5) Report | 6) Cost Analysis

Monday, September 28, 2015 Run complete: 0 error(s).

The schematic diagram shows a feed stream entering a membrane module from the left. The module is represented by a green trapezoidal shape. A concentrate stream exits from the top right, and a permeate stream exits from the bottom right. A dashed box highlights the internal structure of the module, showing a diagonal line representing the membrane surface.

## To Use ISD Feature:

1. Complete design with single stage array
2. Increase number of stages to 2
3. Adjust number of elmts / vessel in stage 1
4. Uncheck "Use same element in the pass"
5. Select element type for stage 1

# Internally Staged Design – Stage 2



ROSA Control Panel - Advanced ROSA

File Options Help

System Permeate Flow: 693.99 gpm System Feed Flow: 1542.16 gpm System Recovery: 45.00%

System Configuration

System Permeate Flow: 693.99 gpm  
System Feed Flow: 1542.16 gpm  
System Recovery: 45.00%

10.8

System Configuration

Feed

Concentrate

Permeate

1) Project Information | 2) Feedwater Data | 3) Scaling Information | 4) System Configuration | 5) Report | 6) Cost Analysis

Monday, September 28, 2015 Run complete: 0 error(s).

**Internally-Staged Design Information**

For each stage beyond the first stage, the ISD checkbox can only be active when all three of the following conditions are met:

1. "Back pressure" is the same as the previous stage.
2. "Pressure vessels in each stage" is the same as the previous stage.
3. "Boost pressure" is 'None'.

**Configuration for Stage 2 in Pass 1**

Stage in Pass: Stage 2

Boost: None psig Pump Efficiency: 80.0 %

Boost (2-pass): Calc

Back Pressure: None psig

Same back pressure for all stages

Pressure vessels in each stage: 30

**7** Elements in each vessel: 4

Total elements in stage: 120

**8** Products: SEAMAXX

Use the same element in the pass

**9**  ISD

**To Use ISD Feature:**

6. Click on Stage 2 to activate it
7. Set # elmts to total minus # Stg 1 elmts
8. Select element type for stage 2
9. Check ISD box to join vessels

# Internally Staged Design – ROSA Report



Case-specific: ISD - SW3oXHR-44oi - SEAMAXX

## System Details

Feed Flow to Stage 1	1542.16 gpm	Pass 1 Permeate Flow	693.99 gpm	Osmotic Pressure:	
Raw Water Flow to System	1542.16 gpm	Pass 1 Recovery	45.00 %	Feed	381.55 psig
Feed Pressure	795.30 psig	Feed Temperature	24.0 C	Concentrate	712.31 psig
Flow Factor	1.00	Feed TDS	36042.89 mg/l	Average	546.93 psig
Chem. Dose	None	Number of Elements	210	Average NDP	253.84 psig
Total Active Area	92400.00 ft <sup>2</sup>	Average Pass 1 Flux	10.82 gfd	Power	667.00 kW
Water Classification: Seawater with DOW Ultrafiltration, SDI < 2.5				Specific Energy	16.02 kWh/kgal

Stage	Element	#PV	#Ele	Feed Flow (gpm)	Feed Press (psig)	Recirc Flow (gpm)	Conc Flow (gpm)	Conc Press (psig)	Perm Flow (gpm)	Avg Flux (gfd)	Perm Press (psig)	Boost Press (psig)	Perm TDS (mg/l)
1	SW3oXHR-44oi	30	3	542.16	795.30	0.00	1214.43	780.24	327.72	11.92	0.00	0.00	77.73
2	SEAMAXX	30	4	1214.43	780.24	0.00	848.16	767.47	366.27	9.00	0.00	0.00	475.29

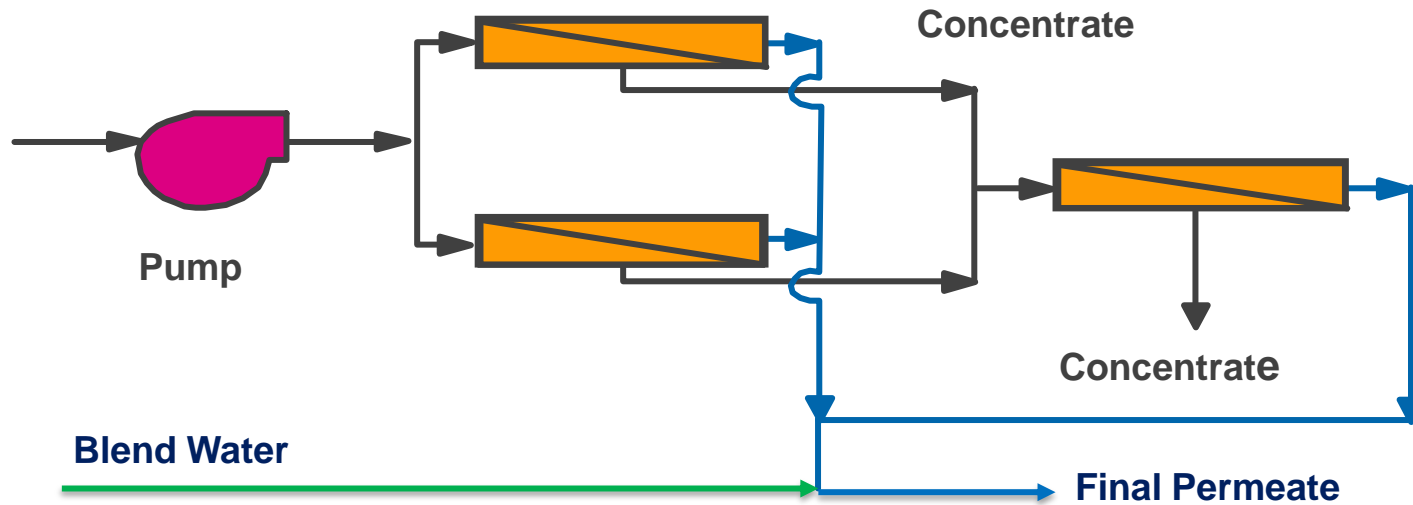
Name	Feed	Adjusted Feed	Pass Streams (mg/l as Ion)					
			Concentrate		Permeate			
			Stage 1	Stage 2	Stage 1	Stage 2	Total	
NH4+ + NH3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	405.00	405.00	514.01	733.15	1.06	6.54	3.95	
Na	12853.13	12853.15	16313.94	23282.51	28.67	176.89	106.90	
Mg	183.00	183.00	232.37	332.62	0.04	0.24	0.14	
Ca	410.00	410.00	520.62	745.22	0.08	0.52	0.32	
Sr	5.61	5.61	7.12	10.20	0.00	0.01	0.00	
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
CO3	16.73	16.73	21.99	32.81	0.00	0.00	0.00	
HCO3	142.40	142.40	179.54	253.64	0.60	3.08	1.90	
NO3	0.24	0.24	0.30	0.42	0.01	0.03	0.02	
Cl	19500.00	19500.00	24750.20	35319.28	44.65	275.42	166.44	
F	0.57	0.57	0.72	1.03	0.00	0.01	0.01	
SO4	2500.00	2500.00	3174.46	4543.50	0.68	4.20	2.53	
SiO2	4.00	4.00	5.08	7.23	0.01	0.09	0.05	
Boron	3.89	3.89	4.84	6.31	0.34	1.44	0.92	
CO2	0.74	0.74	1.01	1.61	0.70	0.91	0.82	
TDS	36042.87	36042.89	45748.03	65297.65	77.73	475.29	287.54	
pH	8.00	8.00	7.95	7.93	6.12	6.65	6.51	

## Design Warnings

-None-



# RO with Feed Water Blending





# RO with Feed Water Blending



ROSA Control Panel - Advanced ROSA

System Pervate Flow: 694.02 gpm    System Feed Flow: 845.75 gpm    System Recovery: 82.06%

No. Passes: 1    Current Pass: 1    Dosing Chemical: None    No Degasification

**Flow Calculator**

Pass	Feed Flow (gpm)	Recovery (%)	Pervate Flow (gpm)	Flux (gfd)	Pervate Split (%)
Pass 1	758.78	80.00	607.02	13.51	0
Pass 2	0.00	0.00	0.00	0.00	

Specify     Specify     Specify

Specify two of the three parameters:

Blend    87 gpm

**Permeate Flow + Blend Flow = Total Product Flow**

Buttons: Help, Recalculate, Reset, Cancel, Accept Changes and Close

1) Project Information | 2) Feedwater Data | 3) Scaling Information | 4) System Configuration | 5) Report | 6) Cost Analysis

Monday, September 28, 2015    Run complete: 0 error(s).

# RO with Feed Water Blending – ROSA Report



## System Details

Feed Flow to Stage 1	758.75 gpm	Pass 1 Permeate Flow	607.02 gpm	Osmotic Pressure:	
Raw Water Flow to System	845.75 gpm	Pass 1 Recovery	80.00 %	Feed	13.43 psig
Feed Pressure	109.63 psig	Feed Temperature	25.0 C	Concentrate	62.42 psig
Flow Factor	0.85	Feed TDS	1498.73 mg/l	Average	37.92 psig
Chem. Dose	None	Number of Elements	147	Average NDP	67.75 psig
Total Active Area	64680.00 ft <sup>2</sup>	Average Pass 1 Flux	13.31 gfd	Power	45.24 kW
Water Classification: Well Water SDI < 3		Bypass Blending Flow	87.00 gpm	Specific Energy	1.09 kWh/kgal
System Recovery	82.06 %	Total Blended Product	694.02 gpm		

Stage	Element	#PV	#Ele	Feed Flow (gpm)	Feed Press (psig)	Recirc Flow (gpm)	Conc Flow (gpm)	Conc Press (psig)	Perm Flow (gpm)	Avg Flux (gfd)	Perm Press (psig)	Boost Press (psig)	Perm TDS (mg/l)
1	ECO-440i	14	7	758.75	109.63	0.00	279.69	97.31	479.06	16.00	0.00	0.00	11.28
2	ECO-440i	7	7	279.69	97.31	0.00	151.73	87.71	127.96	8.55	0.00	0.00	63.15

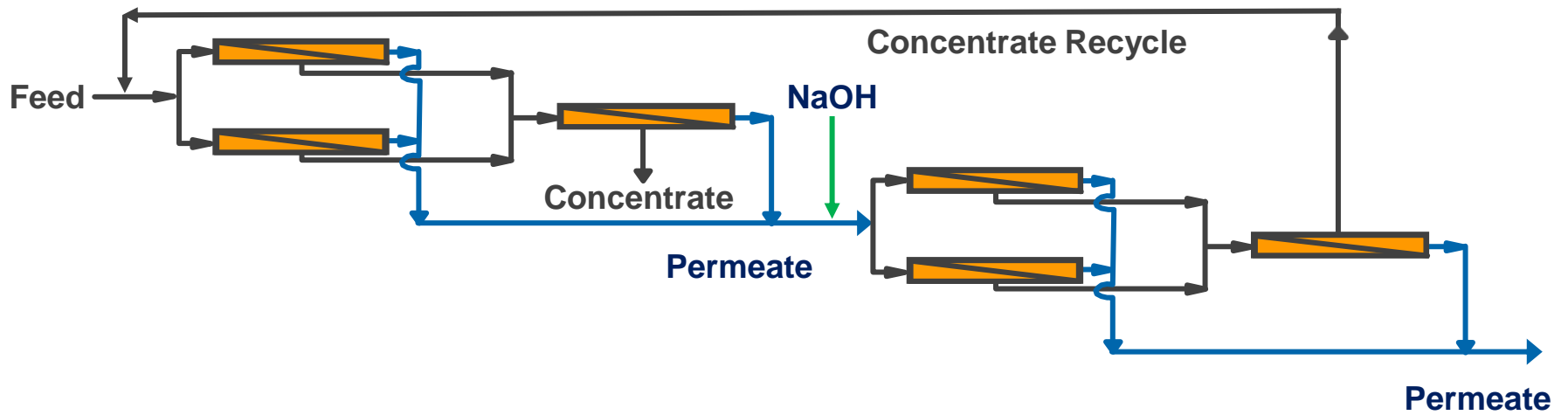
Pass Streams (mg/l as Ion)									
Name	Feed	Adjusted Feed	Concentrate		Permeate			Blended Total	
			Stage 1	Stage 2	Stage 1	Stage 2	Total		
NH4+ + NH3	0.09	0.11	0.31	0.55	0.02	0.04	0.03	0.02	
K	10.00	10.00	26.91	48.96	0.13	0.76	0.26	1.48	
Na	245.00	245.04	660.65	1206.25	2.39	13.73	4.78	34.90	
Mg	70.00	70.00	189.34	347.48	0.33	1.83	0.64	9.34	
Ca	160.00	160.00	432.81	794.35	0.73	4.14	1.44	21.32	
Sr	1.80	1.80	4.87	8.94	0.01	0.05	0.02	0.24	
Ba	0.01	0.01	0.03	0.05	0.00	0.00	0.00	0.00	
CO3	9.48	9.48	28.29	55.13	0.00	0.01	0.00	0.38	
HCO3	200.00	200.00	532.52	961.35	3.29	17.13	6.20	32.05	
NO3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Cl	630.23	630.23	1702.94	3119.81	3.95	22.95	7.95	85.96	
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
SO4	160.00	160.00	433.32	796.78	0.43	2.38	0.84	20.79	
SiO2	12.00	12.00	32.49	59.77	0.04	0.15	0.06	1.56	
Boron	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
CO2	0.56	0.56	1.81	3.95	0.59	1.64	0.81	0.26	
TDS	1498.67	1498.73	4044.51	7399.43	11.28	63.15	22.21	208.06	
pH	8.60	8.60	8.44	8.30	6.95	7.20	7.08	8.24	

## Design Warnings

-None-



# 2 Pass RO





# 2 Pass RO – Pass 1



**ROSA Control Panel - Advanced ROSA**

File Options Help

System Permeate Flow: 693.99 gpm    System Feed Flow: 898.12 gpm    System Recovery: 77.27%

**No. Passes**    Current Pass    Dosing Chemical: NaOH     No Degasification  
 1     2     1     2    Adjusted pH: 9.5     % Carbon Removal    None  
 CO2 Pressure (atm)

**Configuration for Pass 1**

Stages in Pass: 2    Permeate Flow: 816.54 gpm    Recirculation Loops  
Flow Factor: 1.00    Recovery: 80.00 %     Blend Permeate    None gpm  
Operating Temp: 25.0 °C    Feed Flow: 1.021 gpm     Pass 1 Conc to Pass 1 Feed    None gpm  
Permeate Flux: 14.00 gfd     Pass 2 Conc to Pass 1 Feed    122.47 gpm    Max

**Configuration for Stage 1 in Pass 1**

Stage in Pass: Stage 1     ISD    ?  
Feed Pressure: None psig    Pump Efficiency: 80.0 %  
Boost (2-pass): Calc  
Back Pressure: None psig  
 Same back pressure for all stages  
Pressure vessels in each stage: 20  
Elements in each vessel: 7  
Total elements in stage: 140  
Products: BW30-400/34i    Specs  
 Use the same element in the pass

**System Configuration**

1) Project Information    2) Feedwater Data    3) Scaling Information    4) System Configuration    5) Report    6) Cost Analysis

Monday, September 28, 2015    Run complete: 0 error(s).

# 2 Pass RO – Pass 2



**ROSA Control Panel - Advanced ROSA**

File Options Help

System Pervate Flow: 693.99 gpm    System Feed Flow: 898.12 gpm    System Recovery: 77.27%

No. Passes:  1  2    Current Pass:  1  2

Dosing Chemical: **NaOH**    Adjusted pH: 9.5

No Degasification  
 % Carbon Removal: None  
 CO2 Pressure (atm)

**Configuration for Pass 2**

Stages in Pass: 2    Pervate Flow: 693.99 gpm    Recirculation Loops:  
Flow Factor: 0.85    Recovery: 85.00 %     Blend Pervate: None gpm  
Operating Temp: 25.0 °C    Feed Flow: 816.54 gpm     Pass 2 Conc to Pass 2 Feed: None gpm  
Pervate Flux: 20.28 gfd     Pass 2 Conc to Pass 1 Feed: None gpm    Max

**Configuration for Stage 1 in Pass 2**

Stage in Pass: Stage 1     ISD ?    Pump Efficiency: 80.0 %  
Feed Pressure: None psig  
Boost (2-pass): Calc  
Back Pressure: None psig  
 Same back pressure for all stages  
Pressure vessels in each stage: 12  
Elements in each vessel: 7  
Total elements in stage: 84  
Products: BW30-440i    Specs  
 Use the same element in the pass

**System Configuration**

1) Project Information | 2) Feedwater Data | 3) Scaling Information | 4) System Configuration | 5) Report | 6) Cost Analysis

Monday, September 28, 2015    Run complete: 0 error(s).



# 2 Pass RO – Flow Calculator



**Flow Calculator**

**Pass 1**

<u>Feed Flow</u>	<u>Recovery</u>	<u>Permeate Flow</u>	<u>Flux</u>	<u>Permeate Split</u>
<input type="text" value="1020.58"/> gpm	<input type="text" value="80.00"/> %	<input type="text" value="816.46"/> gpm	<input type="text" value="14.00"/> gfd	<input type="text" value="0.00"/> %
<input type="checkbox"/> Specify	<input checked="" type="checkbox"/> Specify			

To calculate the system flows based on pass 1 feed, specify two parameters in pass 1, plus one parameter in pass 2.

Blend  gpm

**Pass 2**

<u>Feed Flow</u>	<u>Recovery</u>	<u>Permeate Flow</u>	<u>Flux</u>	<u>Final Permeate</u>
<input type="text" value="816.46"/> gpm	<input type="text" value="85.00"/> %	<input type="text" value="693.99"/> gpm	<input type="text" value="20.28"/> gfd	<input type="text" value="693.99"/> gpm
	<input checked="" type="checkbox"/> Specify	<input checked="" type="checkbox"/> Specify		

To calculate the system flows based on pass 2 product, specify two parameters in pass 2, plus one parameter in pass 1.



# 2 Pass RO – Pass 1 ROSA Report



Case-specific: 2 Pass RO

## System Details -- Pass 1

Feed Flow to Stage 1	1020.59 gpm	Pass 1 Permeate Flow	816.56 gpm	Osmotic Pressure:	
Raw Water Flow to System	898.12 gpm	Pass 1 Recovery	80.01 %	Feed	17.28 psig
Feed Pressure	156.37 psig	Feed Temperature	25.0 C	Concentrate	81.01 psig
Flow Factor	1.00	Feed TDS	1793.34 mg/l	Average	49.15 psig
Chem. Dose	None	Number of Elements	210	Average NDP	104.19 psig
Total Active Area	84000.00 ft <sup>2</sup>	Average Pass 1 Flux	14.00 gfd	Power	86.80 kW
Water Classification: Well Water SDI < 3				Specific Energy	1.77 kWh/kgal
System Recovery	77.27 %			Conc. Flow from Pass 2	122.47 gpm

Stage	Element	#PV	#Ele	Feed Flow (gpm)	Feed Press (psig)	Recirc Flow (gpm)	Conc Flow (gpm)	Conc Press (psig)	Perm Flow (gpm)	Avg Flux (gfd)	Perm Press (psig)	Boost Press (psig)	Perm TDS (mg/l)
1	BW30-400/34i	20	7	1020.59	156.37	0.00	392.37	141.69	628.26	16.16	0.00	0.00	17.95
2	BW30-400/34i	10	7	392.37	141.69	0.00	204.06	130.69	188.30	9.68	0.00	0.00	68.03

Name	Feed	Pass Streams (mg/l as ion)										
		Adjusted Feed		Concentrate		Permeate						
		Initial	After Recycles	Stage 1	Stage 2	Stage 1	Stage 2	Total	Stage 1	Stage 2	Total	
NH4+ + NH3	0.11	0.11	0.10	0.26	0.49	0.01	0.01	0.01	0.01	0.01	0.01	0.01
K	10.00	10.00	8.95	23.10	44.02	0.11	0.43	0.11	0.43	0.11	0.43	0.18
Na	443.00	443.00	398.39	1028.58	1960.65	4.82	18.51	4.82	18.51	4.82	18.51	7.98
Mg	70.00	70.00	62.13	160.96	308.11	0.41	1.51	0.41	1.51	0.41	1.51	0.66
Ca	160.00	160.00	141.98	367.89	704.25	0.90	3.38	0.90	3.38	0.90	3.38	1.47
Sr	1.80	1.80	1.60	4.14	7.92	0.01	0.04	0.01	0.04	0.01	0.04	0.02
Ba	0.01	0.01	0.01	0.02	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO3	1.65	1.65	2.28	9.85	25.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HCO3	200.00	200.00	182.94	463.91	871.22	2.56	9.15	2.56	9.15	2.56	9.15	4.08
NO3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cl	934.40	944.75	842.67	2178.46	4158.80	8.43	32.41	8.43	32.41	8.43	32.41	13.96
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SO4	160.00	160.00	141.61	367.35	704.22	0.62	2.29	0.62	2.29	0.62	2.29	1.01
SiO2	12.00	12.00	10.67	27.62	52.82	0.09	0.31	0.09	0.31	0.09	0.31	0.14
Boron	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO2	3.41	3.41	2.00	4.04	7.57	2.46	5.01	2.46	5.01	2.46	5.01	3.05
TDS	1992.98	2003.33	1793.34	4632.16	8837.60	17.95	68.03	17.95	68.03	17.95	68.03	29.49
pH	7.80	7.80	8.00	8.02	7.96	6.22	6.44	6.22	6.44	6.22	6.44	6.32



# 2 Pass RO – Pass 2 ROSA Report



Case-specific: 2 Pass RO

## System Details -- Pass 2

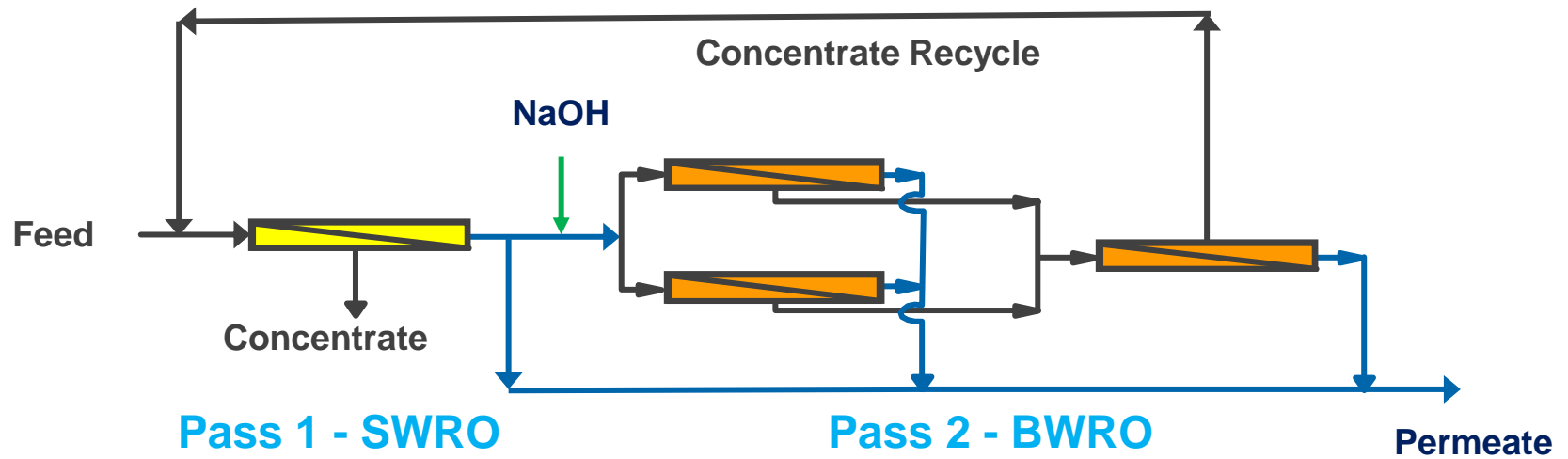
Feed Flow to Stage 1	816.56 gpm	Pass 2 Permeate Flow	693.99 gpm	Osmotic Pressure:	
Raw Water Flow to System	898.12 gpm	Pass 2 Recovery	84.99 %	Feed	0.38 psig
Feed Pressure	202.72 psig	Feed Temperature	25.0 C	Concentrate	2.49 psig
Flow Factor	0.85	Feed TDS	37.01 mg/l	Average	1.44 psig
Chem. Dose (100% NaOH)	4.82 mg/l	Number of Elements	112	Average NDP	175.94 psig
Total Active Area	49200.00 ft <sup>2</sup>	Average Pass 2 Flux	20.28 gfd	Power	90.02 kW
Water Classification: RO Permeate SDI < 1				Specific Energy	2.16 kWh/kgal
System Recovery	77.27 %				

Stage	Element	#PV	#Ele	Feed Flow (gpm)	Feed Press (psig)	Recirc Flow (gpm)	Conc Flow (gpm)	Conc Press (psig)	Perm Flow (gpm)	Avg Flux (gfd)	Perm Press (psig)	Boost Press (psig)	Perm TDS (mg/l)
1	BW30-440i	12	7	816.56	202.72	0.00	274.13	168.99	542.43	21.13	0.00	0.00	0.17
2	BW30-440i	4	7	274.13	168.99	0.00	122.58	131.58	151.56	17.71	0.00	0.00	0.47

Pass Streams (mg/l as Ion)							
Name	Feed	Adjusted Feed	Concentrate		Permeate		Total
			Stage 1	Stage 2	Stage 1	Stage 2	
NH4+ + NH3	0.01	0.00	0.02	0.03	0.00	0.00	0.00
K	0.18	0.18	0.55	1.22	0.00	0.00	0.00
Na	7.98	10.75	31.95	71.32	0.03	0.11	0.05
Mg	0.66	0.66	1.96	4.39	0.00	0.00	0.00
Ca	1.47	1.47	4.38	9.78	0.00	0.01	0.00
Sr	0.02	0.02	0.05	0.11	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO3	0.00	1.14	5.58	15.26	0.00	0.00	0.00
HCO3	4.08	7.14	19.02	39.60	0.03	0.09	0.04
NO3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cl	13.96	13.96	41.49	92.62	0.04	0.14	0.06
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SO4	1.01	1.01	3.00	6.70	0.00	0.00	0.00
SiO2	0.14	0.14	0.41	0.91	0.00	0.00	0.00
Boron	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO2	3.05	0.00	0.01	0.01	0.00	0.00	0.00
TDS	29.49	37.01	109.24	242.89	0.17	0.47	0.24
pH	6.32	9.50	9.70	9.75	8.62	8.82	8.67



# 2 Pass RO with Partial 2<sup>nd</sup> Pass



# 2 Pass RO with Partial 2<sup>nd</sup> Pass



**ROSA Control Panel - Advanced ROSA**

File Options Help

System Pervate Flow: 693.93 gpm    System Feed Flow: 1622.90 gpm    System Recovery: 42.76%

No. Passes:  1  2    Current Pass:  1  2

Dosing Chemical: NaOH    Adjusted pH: 10

No Degasification  
 % Carbon Removal: None  
 CO2 Pressure (atm)

**Configuration for Pass 1**

Stages in Pass: 1    Pervate Flow: 759.93 gpm    Recirculation Loops:  Blend Pervate: 100.00 gpm

Flow Factor: 0.85    Recovery: 45.00 %     Pass 1 Conc to Pass 1 Feed: None gpm

Operating Temp: 31.0 °C    Feed Flow: 1,689 gpm     Pass 2 Conc to Pass 1 Feed: 65.99 gpm [Max]

Permeate Flux: 8.88 gfd

**Configuration for Stage 1 in Pass 1**

Stage in Pass: Stage 1     ISD ?

Feed Pressure: None psig    Pump Efficiency: 80.0 %

Boost (2-pass): Calc

Back Pressure: None psig

Same back pressure for all stages

Pressure vessels in each stage: 40

Elements in each vessel: 7

Total elements in stage: 280

Products: SW30XLE-440i    [Specs]

Use the same element in the pass

**System Configuration**

1) Project Information    2) Feedwater Data    3) Scaling Information    4) System Configuration    5) Report    6) Cost Analysis

Monday, September 28, 2015    Run complete: 0 error(s).



# 2 Pass RO with Partial 2<sup>nd</sup> Pass



Flow Calculator

Pass 1

<u>Feed Flow</u>	<u>Recovery</u>	<u>Permeate Flow</u>	<u>Flux</u>	<u>Permeate Split</u>
1688.71 gpm	45.00 %	759.92 gpm	8.88 gfd	0 %
<input type="checkbox"/> Specify	<input checked="" type="checkbox"/> Specify			

To calculate the system flows based on pass 1 feed, specify two parameters in pass 1, plus one parameter in pass 2.

Blend 100 gpm

Pass 2

<u>Feed Flow</u>	<u>Recovery</u>	<u>Permeate Flow</u>	<u>Flux</u>	<u>Final Permeate</u>
659.92 gpm	90.00 %	593.93 gpm	19.09 gfd	693.93 gpm
	<input checked="" type="checkbox"/> Specify	<input checked="" type="checkbox"/> Specify		

To calculate the system flows based on pass 2 product, specify two parameters in pass 2, plus one parameter in pass 1.

Buttons: Help, Recalculate, Reset, Cancel, Accept Changes and Close

Pass 2 Permeate Flow + Blend Flow = Final Permeate Flow



# 2 Pass RO with Partial 2<sup>nd</sup> Pass - ROSA



Case-specific: 2 Pass RO with Partial 2nd Pass

## System Details -- Pass 1

Feed Flow to Stage 1	1688.89 gpm	Pass 1 Permeate Flow	760.01 gpm	Osmotic Pressure:	
Raw Water Flow to System	1622.90 gpm	Pass 1 Recovery	45.00 %	Feed	433.70 psig
Feed Pressure	881.75 psig	Feed Temperature	31.0 C	Concentrate	816.00 psig
Flow Factor	0.85	Feed TDS	39878.76 mg/l	Average	624.85 psig
Chem. Dose	None	Number of Elements	280	Average NDP	252.14 psig
Total Active Area	123200.00 ft <sup>2</sup>	Average Pass 1 Flux	8.88 gfd	Power	809.86 kW
Water Classification: Seawater with DOW Ultrafiltration, SDI < 2.5		Bypass Blending Flow	100.00 gpm	Specific Energy	17.76 kWh/kgal
System Recovery	42.75 %			Conc. Flow from Pass 2	65.99 gpm

Stage	Element	#PV	#Ele	Feed Flow (gpm)	Feed Press (psig)	Recirc Flow (gpm)	Conc Flow (gpm)	Conc Press (psig)	Perm Flow (gpm)	Avg Flux (gfd)	Perm Press (psig)	Boost Press (psig)	Perm TDS (mg/l)
1	SW30XLE-440i	40	7	1688.89	881.75	0.00	928.87	864.26	760.01	8.88	0.00	0.00	338.38

Pass Streams (mg/l as Ion)							
Name	Feed	Adjusted Feed		Concentrate		Permeate	
		Initial	After Recycles	Stage 1	Stage 1	Total	
NH4+ + NH3	0.00	0.00	0.00	0.00	0.00	0.00	
K	405.00	405.00	390.77	707.14	4.10	4.10	
Na	14800.00	14801.49	14276.26	25854.37	125.61	125.61	
Mg	213.00	213.00	204.75	372.14	0.17	0.17	
Ca	440.00	440.00	422.95	768.74	0.34	0.34	
Sr	5.61	5.61	5.39	9.80	0.00	0.00	
Ba	0.00	0.00	0.00	0.00	0.00	0.00	
CO3	24.16	24.16	26.53	50.55	0.00	0.00	
HCO3	142.40	142.40	134.75	240.15	2.13	2.13	
NO3	0.24	0.24	0.24	0.42	0.02	0.02	



# 2 Pass RO with Partial 2<sup>nd</sup> Pass - ROSA



## System Details -- Pass 2

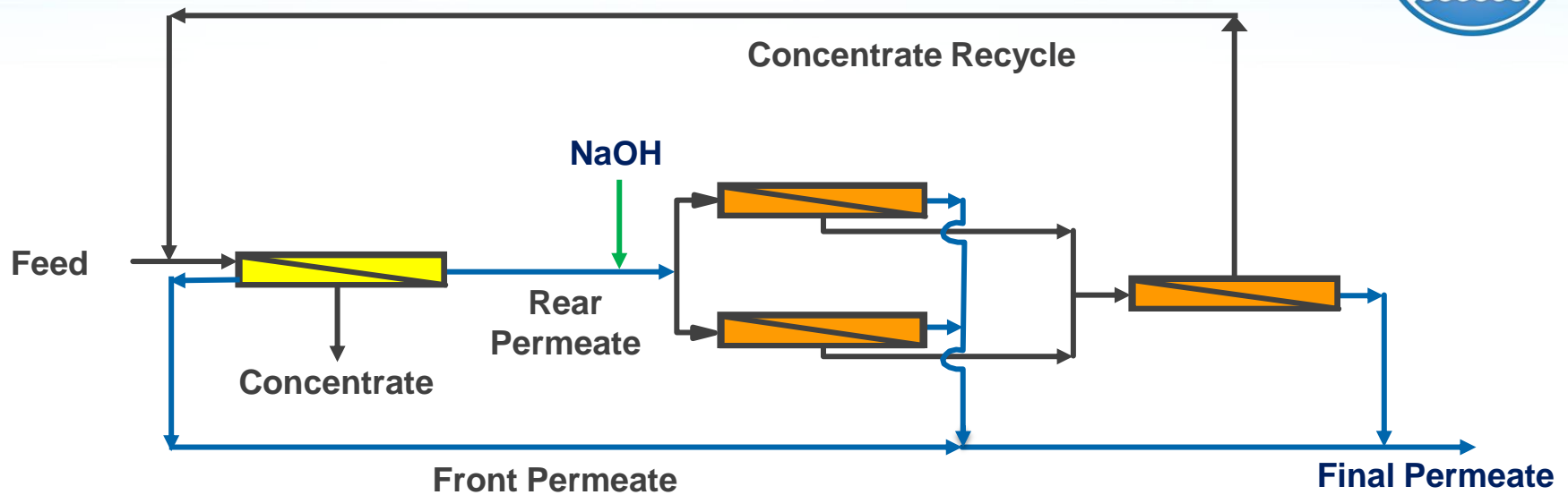
Feed Flow to Stage 1	660.01 gpm	Pass 2 Permeate Flow	593.83 gpm	Osmotic Pressure:	
Raw Water Flow to System	1622.90 gpm	Pass 2 Recovery	89.97 %	Feed	4.12 psig
Feed Pressure	89.38 psig	Feed Temperature	31.0 C	Concentrate	38.44 psig
Flow Factor	0.90	Feed TDS	346.03 mg/l	Average	21.28 psig
Chem. Dose (100% NaOH)	9.58 mg/l	Number of Elements	112	Average NDP	68.61 psig
Total Active Area	44800.00 ft <sup>2</sup>	Average Pass 2 Flux	19.00 gfd	Power	32.08 kW
Water Classification: RO Permeate SDI < 1		Bypass Blending Flow	100.00 gpm	Specific Energy	0.77 kWh/kgal
System Recovery	42.75 %	Total Blended Product	693.83 gpm		

Stage	Element	#PV	#Ele	Feed Flow (gpm)	Feed Press (psig)	Recirc Flow (gpm)	Conc Flow (gpm)	Conc Press (psig)	Perm Flow (gpm)	Avg Flux (gfd)	Perm Press (psig)	Boost Press (psig)	Perm TDS (mg/l)
1	XFRLE-400/34i	12	7	660.01	89.38	0.00	172.98	79.71	487.02	20.87	0.00	0.00	8.04
2	XFRLE-400/34i	4	7	172.98	79.71	0.00	66.17	72.22	106.81	13.73	0.00	0.00	34.71

Pass Streams (mg/l as Ion)									
Name	Feed	Adjusted Feed	Concentrate				Permeate		
			Stage 1		Stage 2		Total	Blended Total	
			Stage 1	Stage 2	Stage 1	Stage 2			
NH4+ + NH3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	4.10	4.10	15.13	38.16	0.18	0.86	0.31	0.85	0.85
Na	125.61	131.11	493.08	1269.92	2.55	11.84	4.22	21.71	21.71
Mg	0.17	0.17	0.64	1.67	0.00	0.00	0.00	0.03	0.03
Ca	0.34	0.34	1.31	3.41	0.00	0.01	0.00	0.05	0.05
Sr	0.00	0.00	0.02	0.04	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO3	0.00	1.18	7.22	22.00	0.01	0.13	0.02	0.06	0.06
HCO3	2.13	1.49	2.69	3.21	0.08	0.28	0.12	0.45	0.45
NO3	0.02	0.02	0.08	0.18	0.00	0.01	0.00	0.01	0.01
Cl	194.81	194.81	732.60	1886.73	3.79	17.62	6.28	33.45	33.45
F	0.01	0.01	0.02	0.06	0.00	0.00	0.00	0.00	0.00
SO4	3.35	3.35	12.71	33.02	0.03	0.12	0.04	0.52	0.52
SiO2	0.06	0.06	0.21	0.56	0.00	0.00	0.00	0.01	0.01
Boron	1.36	1.36	4.74	11.71	0.16	0.43	0.21	0.37	0.37
CO2	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00



# Split Permeate SWRO with Partial 2 Pass Design



- Split permeate SWRO systems withdraw permeate from both ends of the first pass pressure vessels
- Front permeate is lower in salinity and is directly blended into the final permeate stream
- Many split permeate SWRO systems use ISD with elements chosen specifically to reduce front permeate TDS and/or control lead element flux

# Split Permeate SWRO with Partial 2 Pass Design



**ROSA Control Panel - Advanced ROSA**

File Options Help

System Permeate Flow: 1389.15 gpm    System Feed Flow: 3231.72 gpm    System Recovery: 42.98%

No. Passes:  1  2    Current Pass:  1  2

Dosing Chemical: NaOH     No Degasification  
Adjusted pH: 10     % Carbon Removal (None)  
 CO2 Pressure (atm)

**Configuration for Pass 1**

Stages in Pass: 1    Permeate Flow: 1,478 gpm    Recirculation Loops:  
Flow Factor: 0.85    Recovery: 45.00%     Blend Permeate (None gpm)  
Operating Temp: 31.0 °C    Feed Flow: 3,284 gpm     Pass 1 Conc to Pass 1 Feed (None gpm)  
Permeate Flux: 8.64 gfd     Pass 2 Conc to Pass 1 Feed (52.24 gpm) [Max]

**Configuration for Stage 1 in Pass 1**

Stage in Pass: Stage 1     ISD (?)  
Feed Pressure: None psig    Pump Efficiency: 80.0%  
Boost (2-pass): Calc  
Back Pressure: None psig  
 Same back pressure for all stages  
Pressure vessels in each stage: 80  
Elements in each vessel: 7  
Total elements in stage: 560  
Products: SW30XLE-440i [Specs]  
 Use the same element in the pass

**System Configuration**

1) Project Information    2) Feedwater Data    3) Scaling Information    4) System Configuration    5) Report    6) Cost Analysis

Monday, September 28, 2015    Run complete: 0 error(s).



# Split Permeate SWRO – Flow Calculator



**Flow Calculator**

**Pass 1**

<u>Feed Flow</u>	<u>Recovery</u>	<u>Permeate Flow</u>	<u>Flux</u>	<u>Permeate Split</u>
3285.22 gpm	45.00 %	1478.35 gpm	8.64 gfd	40.00 % 591.34 gpm
<input type="checkbox"/> Specify	<input checked="" type="checkbox"/> Specify		<input type="checkbox"/> Blend	

To calculate the system flows based on pass 1 feed, specify two parameters in pass 1, plus one parameter in pass 2.

**Pass 2**

<u>Feed Flow</u>	<u>Recovery</u>	<u>Permeate Flow</u>	<u>Flux</u>	<u>Final Permeate</u>
887.01 gpm	90.00 %	798.31 gpm	20.53 gfd	1389.65 gpm
	<input checked="" type="checkbox"/> Specify	<input checked="" type="checkbox"/> Specify		

To calculate the system flows based on pass 2 product, specify two parameters in pass 2, plus one parameter in pass 1.

**Buttons:** Help, Recalculate, Reset, Cancel, Accept Changes and Close

# Split Permeate SWRO – Pass 1 ROSA Report



Case-specific: Split Permeate 2 Pass RO

## System Details -- Pass 1

Feed Flow to Stage 1	3285.22 gpm	Pass 1 Permeate Flow	1478.31 gpm	Osmotic Pressure:	
Raw Water Flow to System	3285.22 gpm	Pass 1 Recovery	45.00 %	Feed	450.33 psig
Feed Pressure	911.19 psig	Feed Temperature	31.0 C	Concentrate	848.99 psig
Flow Factor	0.85	Feed TDS	41355.45 mg/l	Average	649.66 psig
Chem. Dose	None	Number of Elements	560	Average NDP	290.68 psig
Total Active Area	246400.00 ft <sup>2</sup>	Average Pass 1 Flux	8.64 gfd	Power	1627.95 kW
Water Classification: Seawater with DOW Ultrafiltration, SDI < 2.5		Permeate Split Stream	591.34 gpm	Specific Energy	18.35 kWh/kgal
System Recovery	42.30 %			Conc. Flow from Pass 2	0.00 gpm

Stage	Element	#PV	#Ele	Feed Flow (gpm)	Feed Press (psig)	Recirc Flow (gpm)	Conc Flow (gpm)	Conc Press (psig)	Perm Flow (gpm)	Avg Flux (gfd)	Perm Press (psig)	Boost Press (psi)	Perm TDS (mg/l)
1F	SW30XLE-440i	80	1.4106	3285.22	911.19	0.00	2681.46	906.36	591.34	17.15	0.00	0.00	148.54
1R	SW30XLE-440i	80	5.5894	2681.46	906.36	0.00	1806.92	894.43	874.55	6.40	0.00	0.00	506.86

Name	Feed	Pass Streams (mg/l as Ion)						Permeate				
		Adjusted Feed		Concentrate		Permeate						
		Initial	After Recycles	Stage 1F	Stage 1R	Stage 1F	Stage 1R	Total to Pass 2				
NH4+ + NH3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	405.00	405.00	400.67	490.85	726.83	1.74	6.13	6.13	6.13	6.13	6.13	6.13
Na	14800.00	14801.49	14640.22	17937.48	26579.91	54.31	187.23	187.23	187.23	187.23	187.23	187.23
Mg	213.00	213.00	210.33	257.86	383.29	0.08	0.25	0.25	0.25	0.25	0.25	0.25
Ca	440.00	440.00	434.49	532.67	791.78	0.15	0.51	0.51	0.51	0.51	0.51	0.51
Sr	5.61	5.61	5.54	6.79	10.10	0.00	0.01	0.01	0.01	0.01	0.01	0.01
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO3	24.16	24.16	25.38	31.76	48.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HCO3	142.40	142.40	139.63	170.10	249.53	1.01	3.06	3.06	3.06	3.06	3.06	3.06
NO3	0.24	0.24	0.24	0.29	0.42	0.01	0.03	0.03	0.03	0.03	0.03	0.03
Cl	22192.65	22192.65	21950.81	26893.95	39846.94	84.16	290.46	290.46	290.46	290.46	290.46	290.46
F	0.57	0.57	0.56	0.69	1.02	0.00	0.01	0.01	0.01	0.01	0.01	0.01
SO4	3100.00	3100.00	3061.35	3753.05	5577.96	1.52	4.96	4.96	4.96	4.96	4.96	4.96
SiO2	4.00	4.00	3.96	4.85	7.17	0.02	0.08	0.08	0.08	0.08	0.08	0.08
Boron	4.61	4.61	4.77	5.68	7.57	0.74	1.80	1.80	1.80	1.80	1.80	1.80
CO2	0.62	0.62	0.57	0.75	1.27	0.44	0.57	0.57	0.57	0.57	0.57	0.57
TDS	41353.96	41355.45	40900.42	50112.80	74266.70	147.22	503.04	503.04	503.04	503.04	503.04	503.04
pH	8.00	8.00	8.03	7.99	8.00	6.49	6.82	6.82	6.82	6.82	6.82	6.82



# Split Permeate SWRO – Pass 2 ROSA Report



Case-specific: Split Permeate 2 Pass RO

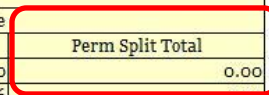
## System Details -- Pass 2

Feed Flow to Stage 1	887.01 gpm	Pass 2 Permeate Flow	798.35 gpm	Osmotic Pressure:	
Raw Water Flow to System	3285.22 gpm	Pass 2 Recovery	90.01 %	Feed	6.13 psig
Feed Pressure	104.67 psig	Feed Temperature	31.0 C	Concentrate	57.22 psig
Flow Factor	0.90	Feed TDS	515.95 mg/l	Average	31.67 psig
Chem. Dose (100% NaOH)	11.54 mg/l	Number of Elements	140	Average NDP	75.94 psig
Total Active Area	56000.00 ft <sup>2</sup>	Average Pass 2 Flux	20.53 gfd	Power	50.49 kW
Water Classification: RO Permeate SDI < 1		Permeate Split Stream	591.34 gpm	Specific Energy	1.05 kWh/kgal
System Recovery	42.30 %	Total System Product	1389.69 gpm		



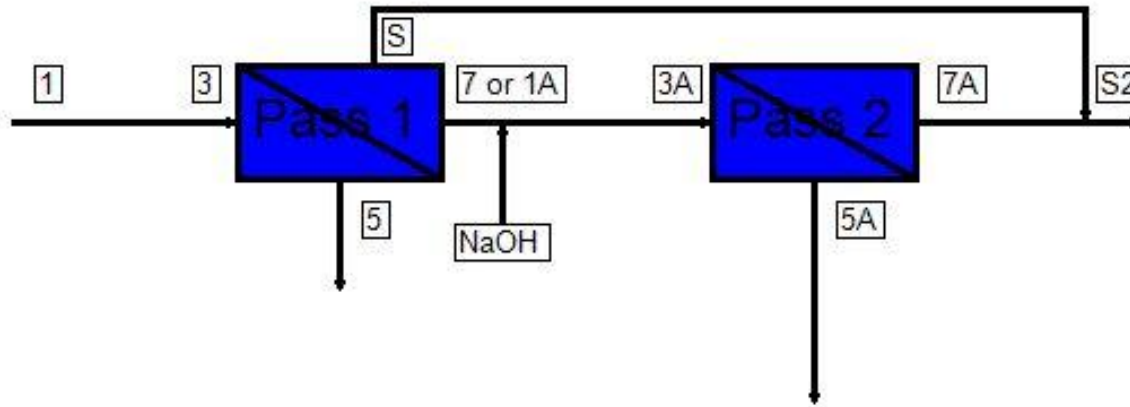
Stage	Element	#PV	#Ele	Feed Flow (gpm)	Feed Press (psig)	Recirc Flow (gpm)	Conc Flow (gpm)	Conc Press (psig)	Perm Flow (gpm)	Avg Flux (gfd)	Perm Press (psig)	Boost Press ()	Perm TDS (mg/l)
1	XFRLE-400/34i	15	7	887.01	104.67	0.00	216.19	94.31	670.81	23.00	0.00	0.00	11.23
2	XFRLE-400/34i	5	7	216.19	94.31	0.00	88.65	86.76	127.54	13.12	0.00	0.00	55.76

Name	Feed	Adjusted Feed	Pass Streams (mg/l as Ion)						Perm Split Total
			Concentrate		Permeate				
			Stage 1	Stage 2	Stage 1	Stage 2	Total		
NH4+ + NH3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	6.18	6.18	24.52	57.73	0.27	1.44	0.46	1.01	1.01
Na	188.80	195.43	790.39	1899.46	3.68	19.47	6.21	26.91	26.91
Mg	0.25	0.25	1.03	2.51	0.00	0.01	0.00	0.03	0.03
Ca	0.52	0.52	2.11	5.13	0.00	0.01	0.00	0.07	0.07
Sr	0.01	0.01	0.03	0.07	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO3	0.00	1.84	11.93	32.96	0.02	0.21	0.03	0.02	0.02
HCO3	3.06	2.11	3.82	4.41	0.12	0.45	0.18	0.53	0.53
NO3	0.03	0.03	0.12	0.27	0.00	0.01	0.00	0.01	0.01
Cl	292.90	292.90	1184.62	2846.85	5.52	29.19	9.30	41.51	41.51
F	0.01	0.01	0.04	0.09	0.00	0.00	0.00	0.00	0.00
SO4	5.01	5.01	20.41	49.50	0.04	0.20	0.07	0.69	0.69
SiO2	0.08	0.08	0.35	0.84	0.00	0.00	0.00	0.01	0.01
Boron	1.75	1.75	6.56	15.13	0.20	0.61	0.26	0.46	0.46
CO2	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.21
TDS	506.86	515.95	2080.18	4990.96	11.23	55.76	18.35	73.75	73.75
pH	6.75	10.00	10.36	10.55	9.42	9.90	9.55	6.43	6.43





# Split Permeate SWRO –Overview ROSA Report



Pass 1				Pass 2			
Stream #	Flow (gpm)	Pressure (psig)	TDS (mg/l)	Stream #	Flow (gpm)	Pressure (psig)	TDS (mg/l)
1	3285.22	0.00	41353.96	1A	1478.31	-	506.86
3	3285.22	911.19	41355.45	3A	887.01	104.67	515.95
5	1806.92	894.43	74893.91	5A	88.65	86.76	4990.96
7	1478.31	-	506.86	7A	798.35	-	18.35
8	591.34	0.00	148.54	S2	1402.11	0.00	73.75
7/1	% Recovery	45.00		7A/1A	% Recovery	90.01	

# Temperature History Effect - SWRO designs

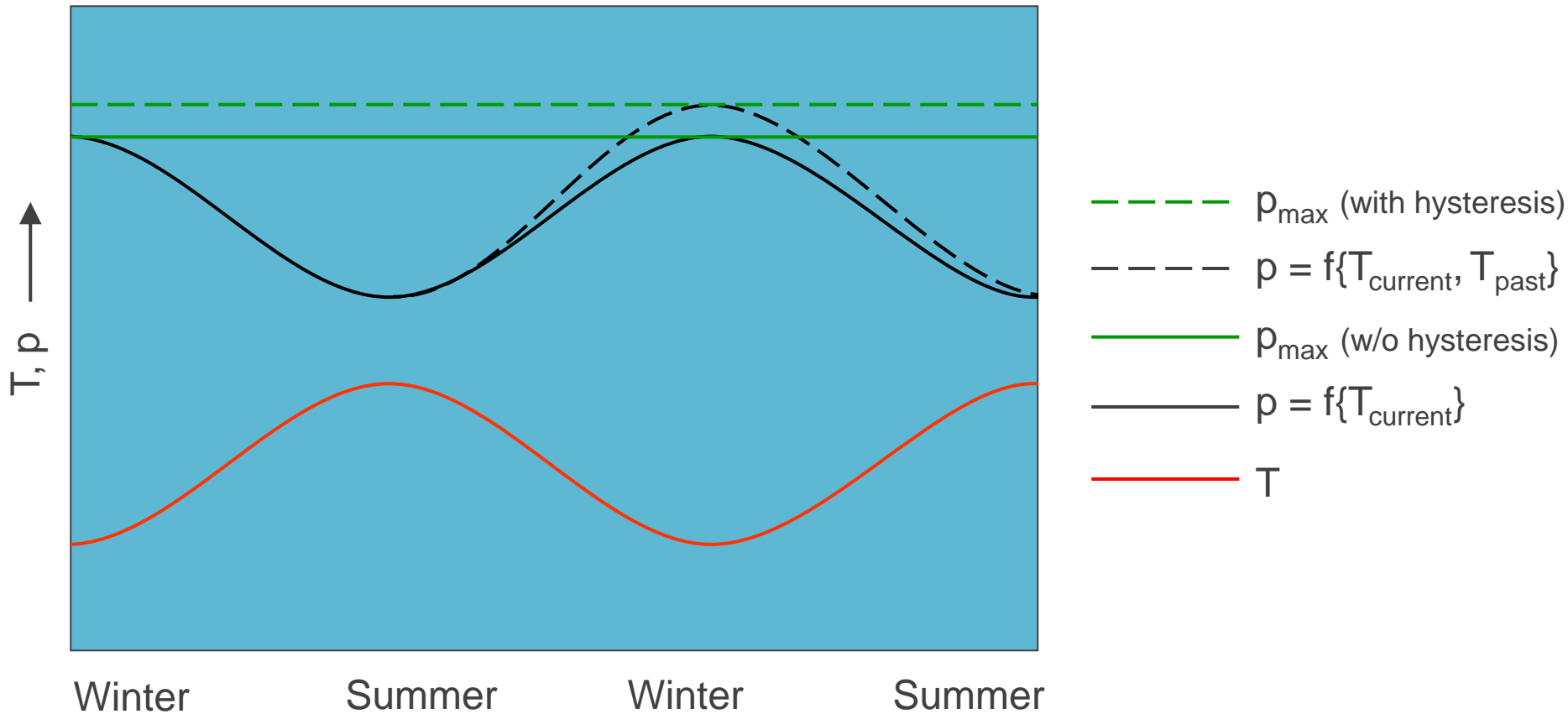


- RO operation at elevated temperatures (35°C and above) causes an irreversible flow loss.
- Flow loss becomes apparent if the system is later operated at lower temperatures (20-35°C).
- This is a phenomenon common to all thin film composite RO membranes operated under similar conditions.

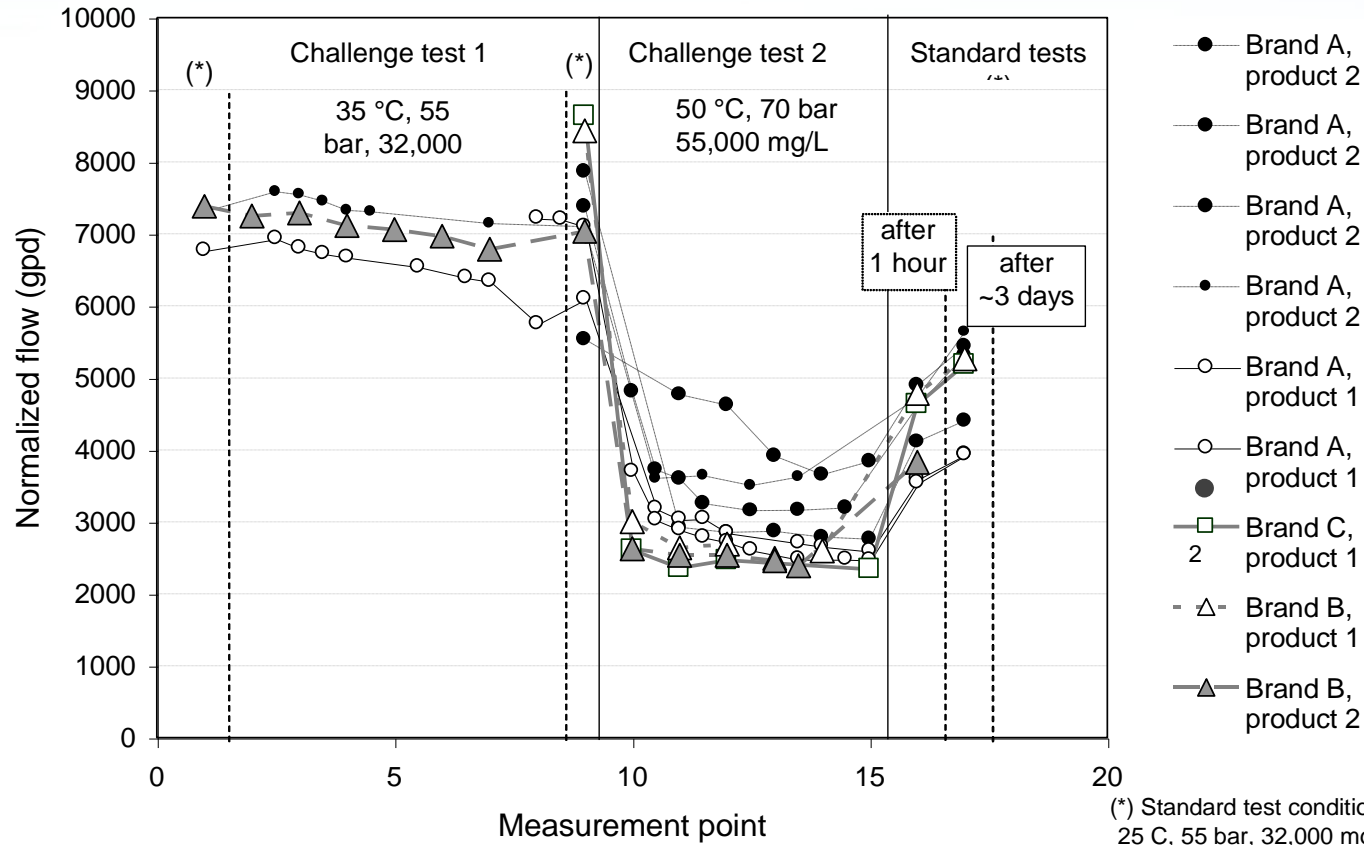
# Up's and Down's : The Temp. Hysteresis



Simplified model for feed pressure “p” as function of feed temperature “T” in an RO system



# High Temp. Tests with SWRO elements



The hysteresis effect is inherent for all polyamide spiral wound RO modules.

# ROSA – Temperature History Effect



ROSA Control Panel - Advanced ROSA

File Options Help

System Permeate Flow: 1389.69 gpm   System Feed Flow: 3285.22 gpm   System Recovery: 42.30%

Water Type: Seawater with DOW Ultrafiltration, SDI < 2.5

Open Water Profile Library

Feed Percentage: 100.0 (%)   Feed Number: 1   Feed Streams: 1

Specify Individual Solutes

Dissolved Solids: 41354.0 mg/l

Parameters

Temperature: 31.0 °C   Max Temp

Rate: 3285.2 gpm

8.0   (38 °C)

High Temperature Effect

To account for irreversible flux loss that is experienced at high operating temperature under high pressure, check the box below and enter the maximum operating temperature that the system will be exposed to:

Account for flux loss at maximum temperature

Maximum Temperature: 38.0 °C

Close

System Temp: 31.0 °C   System pH: 8.00   Save Water Profile to Library

Note: Any changes in raw feedwater composition will affect scaling calculations. Please review scaling calculations.

1) Project Information   2) Feedwater Data   3) Scaling Information   4) System Configuration   5) Report   6) Cost Analysis

Tuesday, September 29, 2015   Run complete: 0 error(s).

# ROSA – Control Panel: Options



The screenshot shows the ROSA Control Panel interface. The 'Options' menu is open, with 'Batch Processor' highlighted. A red arrow points from the 'Batch Processor' menu item to a text box. The text box contains the following text:

**Batch Processor:**  
allows the software to run multiple projections automatically

The interface also shows the 'Project Cases' section with 'Case: 1' selected and buttons for 'Add Case', 'Delete Case', and 'Manage'. The 'Project Preferences' section includes fields for 'Analysis By: Justyna Warczok', 'Company Name: The Dow Chemical Company', 'Balance Analysis With: NaCl', 'Units Set: Flow: m3/h, Pressure: bar', 'Temperature Unit: Celsius (°C)', and 'Default Project Folder: C:\Documents and Settings\U391938\Data\My Documents\DWS\1- Technical Service\Tech'. A 'Small Commercial System' checkbox is also present. The 'DOW Water & Process Solutions' logo is visible in the bottom right of the panel. At the bottom of the window, there is a navigation bar with tabs: '1) Project Information', '2) Feedwater Data', '3) Scaling Information', '4) System Configuration', '5) Report', and '6) Cost Analysis'. The system tray shows the date 'Tuesday, July 20, 2010' and the status 'Ready...'.







## Input Variables

- Flow Factor: Start-up and Long term
- Temperature: Maximum & Minimum and desired number of intermediate points
- Option to activate the “High Temperature Effect”

## Output

- ROSA will generate projections for each temperature at each Flow Factor indicated
- Projections can be stored in the same folder as the ROSA file
- A summary excel file can be generated as well. The parameters to be included in this summary are selected by the user



# Batch Processor



1. Go to options>Batch processor once feedwater & design are defined

2. Input parameters: Indicate temperature range, FF and “high temperature effect”

3. Output parameters: Select from the list those parameters to be included in the summary table

# Batch Processor Example



## Input

Temperature		Flow Factor (FF)		Intermediate points, n <sup>o</sup>
Minimum	Maximum	Start up	Long term	
10°C	30°C	1	0.75 – 0.65	3

*Note: in case of a two pass system, FF for both passes should be indicated.*

## Output

The following projections will be generated

	10°C	15°C	20°C	25°C	30°C
FF 1	√	√	√	√	√
FF 0.7	√	√	√	√	√

# Batch Processor – Output 1



Once all of the projections are finished, the user can save the results as a summary excel file

The screenshot shows a software window titled "Batch Output" containing a table with 10 rows of data. The columns are labeled: FeedTemp, P1FF, FeedTDS, FeedBoron, SysPermFlow, SysPermTDS, SysPermB, and SysRec. The data shows a progression of FeedTemp from 10.00 to 30.00, while other parameters remain constant or change slightly. Below the table are three buttons: "Save as Excel File", "Print", and "Close".

	FeedTemp	P1FF	FeedTDS	FeedBoron	SysPermFlow	SysPermTDS	SysPermB	SysRec
1	10.00	0.70	37054.83	5.02	10099.96	61.03	0.00	0.45
2	10.00	1.00	37054.83	5.02	10099.82	61.81	0.00	0.45
3	15.00	0.70	37054.83	5.02	10099.95	82.12	0.00	0.45
4	15.00	1.00	37054.83	5.02	10100.45	83.32	0.00	0.45
5	20.00	0.70	37054.83	5.02	10099.58	109.48	0.00	0.45
6	20.00	1.00	37054.83	5.02	10101.73	111.25	0.00	0.45
7	25.00	0.70	37054.83	5.02	10099.85	144.61	0.00	0.45
8	25.00	1.00	37054.83	5.02	10100.14	147.14	0.00	0.45
9	30.00	0.70	37054.83	5.02	10099.81	188.94	0.00	0.45
10	30.00	1.00	37054.83	5.02	10099.95	192.42	0.00	0.45

# Batch Processor – Output 2



As a result, the user will get all the projections and the summary excel file

*Note: to ensure projections are saved in the same folder as the original ROSA file → go to options → files and folders and select: save the output file in the same folder as the input file*

ROSA file →

Generated projections

Summary file →

Name	Size	Type	Date Modified
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# ROSA Report – Warnings!



## Design Warnings

WARNING: Maximum recommended element permeate flow rate has been exceeded. Please change your system design to reduce the element permeate flows. (Product: LE-400, Limit: 1.44m<sup>3</sup>/h)  
 WARNING: Maximum element recovery has been exceeded. Please change your system design to reduce the element recoveries. (Product: LE-400, Limit: 19.00%)

## Solubility Warnings

Langelier Saturation Index > 0  
 Stiff & Davis Stability Index > 0  
 BaSO<sub>4</sub> (% Saturation) > 100%  
 Antiscalants may be required. Consult your antisc...

Designs of systems in excess of the guidelines results in a warning on the ROSA Report.

## Stage Details

Stage 1	Element	Recovery	Perm Flow (m <sup>3</sup> /h)	Perm TDS (mg/l)	Feed Flow (m <sup>3</sup> /h)	Feed TDS (mg/l)	Feed Press (bar)
	1	0.12	1.57	11.70	13.36	1290.21	11.02
	2	0.12	1.47	13.56	11.79	1460.17	10.50
	3	0.13	1.39	16.02	10.32	1666.56	10.07
	4	0.15	1.31	19.36	8.93	1923.00	9.72
	5	0.16	1.25	24.04	7.62	2251.13	9.43
	6	0.18	1.10	30.99	6.37	2686.19	9.20
	7	0.21	1.10	41.87	5.20	3286.44	9.03
Stage 2	Element	Recovery	Perm Flow (m <sup>3</sup> /h)	Perm TDS (mg/l)	Feed Flow (m <sup>3</sup> /h)	Feed TDS (mg/l)	Feed Press (bar)
	1	0.12	1.01	50.77	8.21	4152.04	8.56
	2	0.12	0.90	63.99	7.20	4724.16	8.30
	3	0.12	0.79	81.83	6.30	5386.59	8.08
	4	0.12	0.67	106.30	5.52	6141.11	7.90
	5	0.12	0.56	140.36	4.84	6977.61	7.76
	6	0.11	0.45	188.48	4.28	7869.93	7.63
	7	0.09	0.35	256.91	3.83	8774.98	7.53



# Warnings and typical solutions – For one stage systems



Design warning	Solutions
Max. element <b>permeate flow</b> exceeded	3, 5, 7, 10
The <b>concentrate flow</b> less than minimum	1, 5, 4 together with 6
The <b>feed flow</b> greater than maximum	2 unless the feed flow is fixed, 3
Maximum <b>feed pressure</b> exceeded	1, 3, 8
<b>Temperature</b> is above acceptable value	9
Max. element <b>recovery</b> exceeded: <ul style="list-style-type: none"> <li>• If the problem is encountered in front elements</li> <li>• If the problem is encountered in rear elements</li> </ul>	1, 5, 6, 10 1, 5, 6



## Solutions Guide

- |  |                            |  |  |
|--|----------------------------|--|--|
| <p>1 Decrease system recovery</p> <p>2 Increase system recovery</p> <p>3 Reduce average system flux (add membranes, PV)</p> <p>4 Reduce number of PV (increasing average system flux)</p> <p>5 Enable a recirculation loop Pass 1 Conc to Pass 1 Feed (normally not used for SW appl.)</p> | <p>6</p> <p>7</p> <p>8</p> | <p>Increase the number of elements per PV (keeping the same APF*)</p> <p>Decrease the number of elements per PV (keeping the same APF*)</p> <p>Install lower energy membranes or ISD with lower energy membranes</p> | <p>9 Reduce Temp (recommend customer to reduce temp during pretreatment).</p> <p>10 Combine two element types: lower energy elements in rear positions (ISD configuration)</p> |
|--|----------------------------|--|--|

\*APF – Average Permeate Flux  
\*\*PV=Pressure vessel



# Warnings and typical solutions – For multi-stage systems



Design warning	Solutions
Max. element <b>permeate flow</b> exceeded	3, (5), 6, 10, 13
The <b>concentrate flow</b> less than minimum	1, 4, (5), 6, 7, (10 and 11 only for the 1 <sup>st</sup> stage)
The <b>feed flow</b> greater than maximum in any of the stages	2, 3
Maximum <b>feed pressure</b> exceeded	1, 3, 9
<b>Temperature</b> is above acceptable value	12
Max. element <b>recovery</b> exceeded: <ul style="list-style-type: none"> <li>• If the problem is encountered in front elements (front stage/s)</li> <li>• If the problem is encountered in rear elements (rear stage/s)</li> </ul>	1, (5), 6, 7, 10, 13 1, (5), 7

- 1 Decrease system recovery
- 2 Increase system recovery
- 3 Increase number of PV (reducing average system flux)
- 4 Reduce number of PV (increasing average system flux)
- 5 Enable a recirculation loop: Pass 1 Conc to Pass 1 Feed (normally not used for SW appl.)

## Solutions Guide

- 6 Add backpressure in first and/or second stages permeate streams
- 7 Increase the number of elements per PV (keeping the same APF)
- 8 Decrease the number of elements per PV (keeping the same APF)
- 9 Install lower energy membranes or ISD with lower energy membranes
- 10 Add booster pump in first or second stage concentrate
- 11 Use a lower active area membrane element (keeping the same APF)
- 12 Reduce Temp (recommend customer to reduce temp during pretreatment).
- 13 Combine two element types: lower energy elements in second or third stages





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