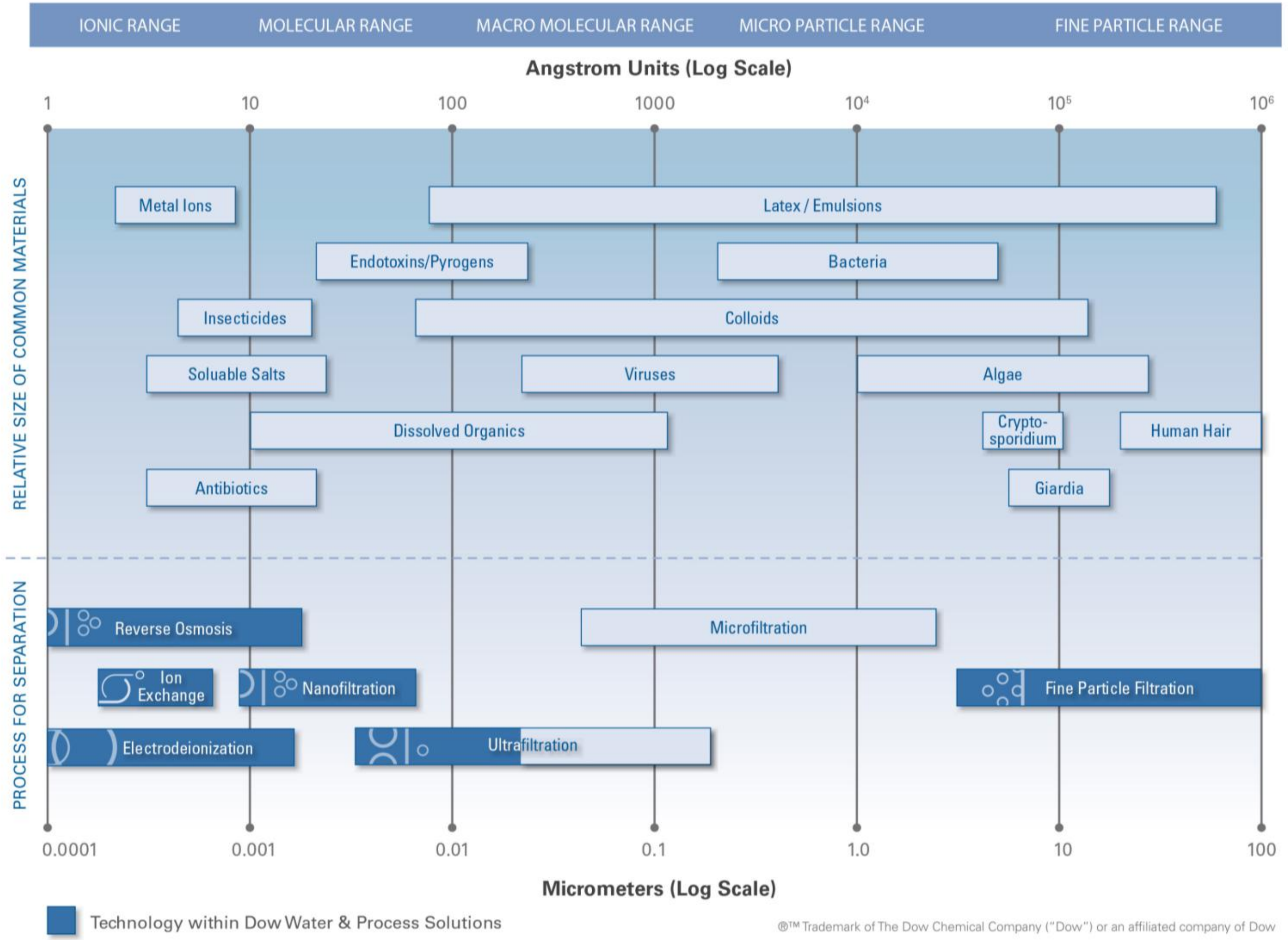
Reverse Osmosis Systems Course Operation & Design

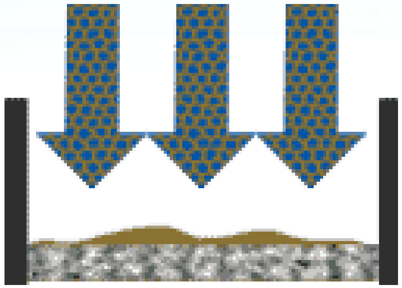
Content

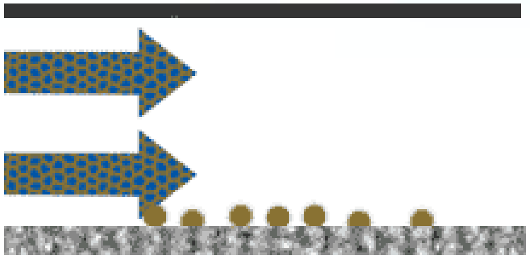
- Filtration spectrum of membranes
- Basics of Reverse Osmosis and equations
- Factors which affect membrane performance
- Thin Film Composites and Spiral Wound Membranes
- Applications and Markets

Filtration spectrum



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

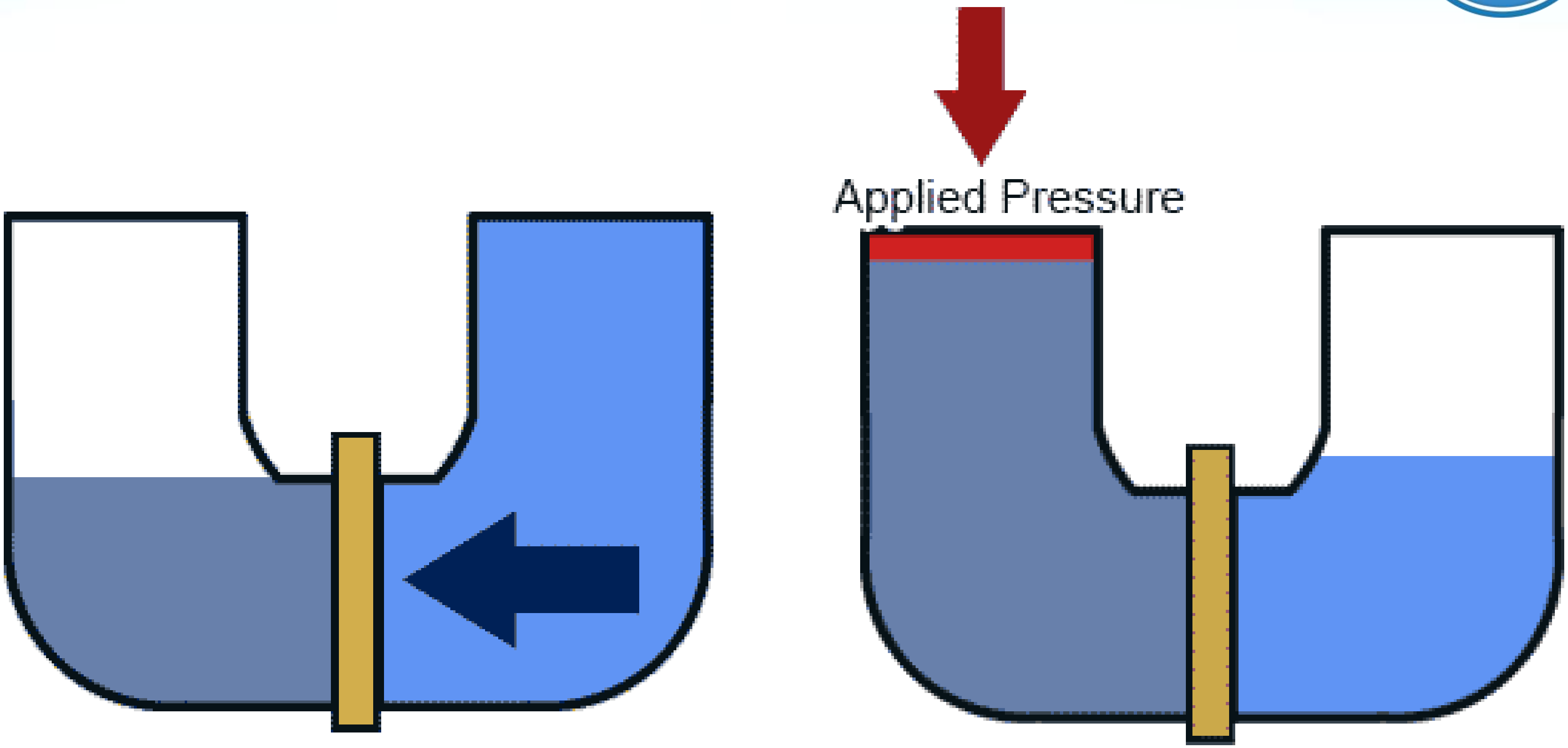
Required for RO/NF:

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

Typical operating pressures of different pressure driven processes

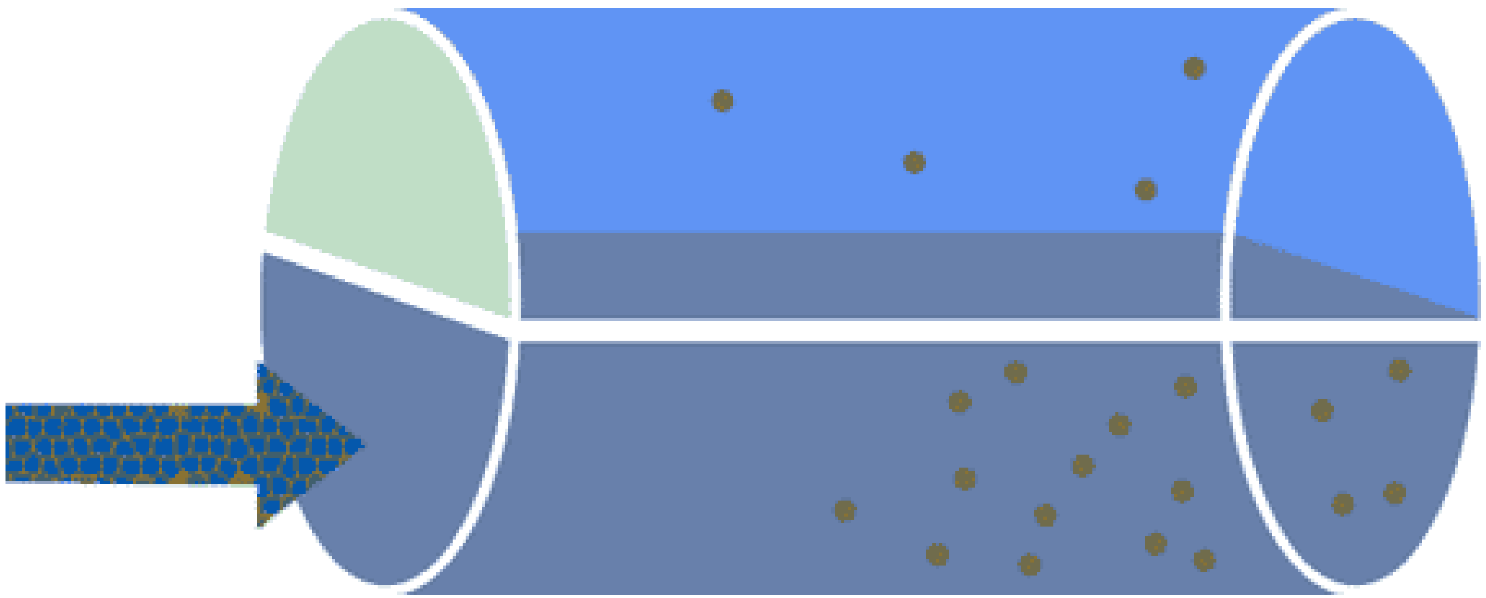
Membrane Process	Typical Operating Pressure Range (bar)	Typical Operating pressure (psi)
Reverse Osmosis Seawater Brackish water	 55 – 76 10 - 40	 800 - 1100 145 - 580
Nanofiltration	3.5 - 15	50 - 220
Ultrafiltration	2 – 7	30 - 100
Microfiltration	0.1-3	1.5 - 45

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:

$$\pi = \phi \, C_i \, RT$$

π - osmotic pressure, atm

ϕ - osmotic pressure coefficient

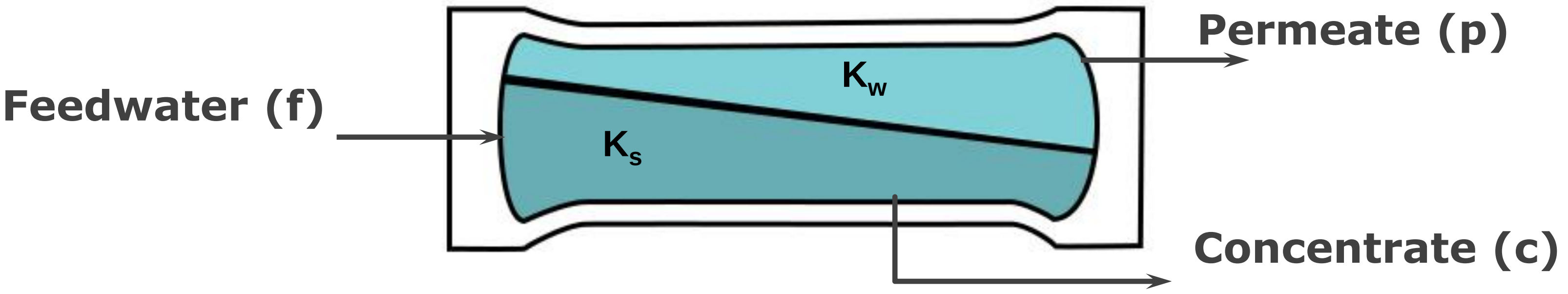
C_i - molar concentrate of the solute, mol/l

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)
ΔP - transmembrane pressure differential [psi]
$\Delta\pi$ - osmotic pressure differential [psi]

$$Fs = Ks\,(\Delta C)$$

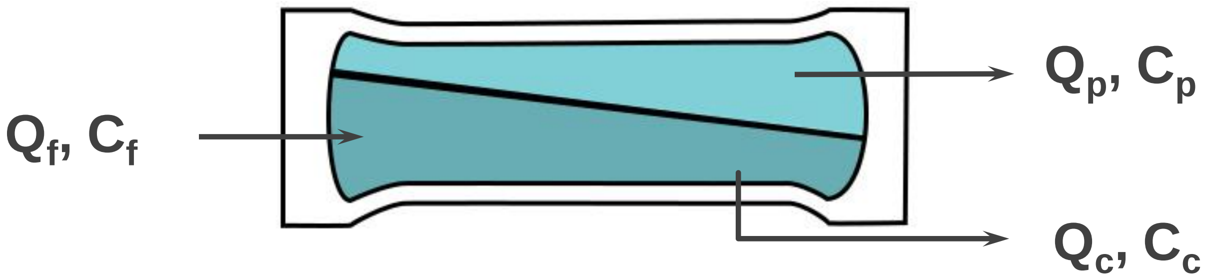
F_s - solute flux [pounds per square foot per day, lbfd]
K_s - solute mass transfer coefficient [gfd] (B value)
ΔC - transmembrane concentration differential [lb/gal]

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]



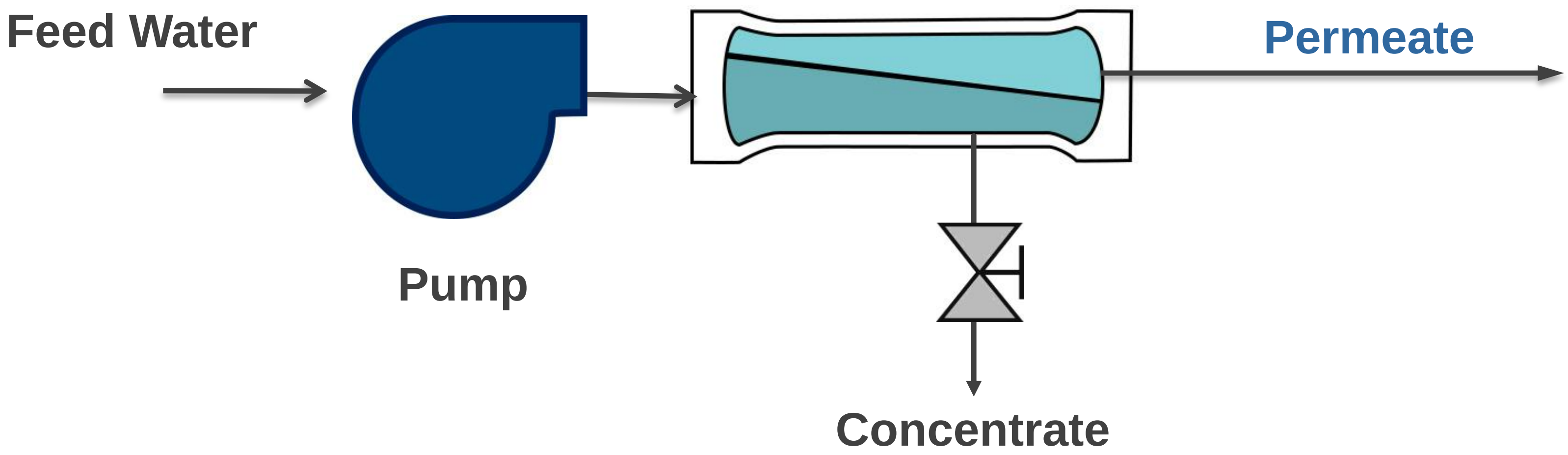
Basic definitions

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

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

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

Simplified RO system



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

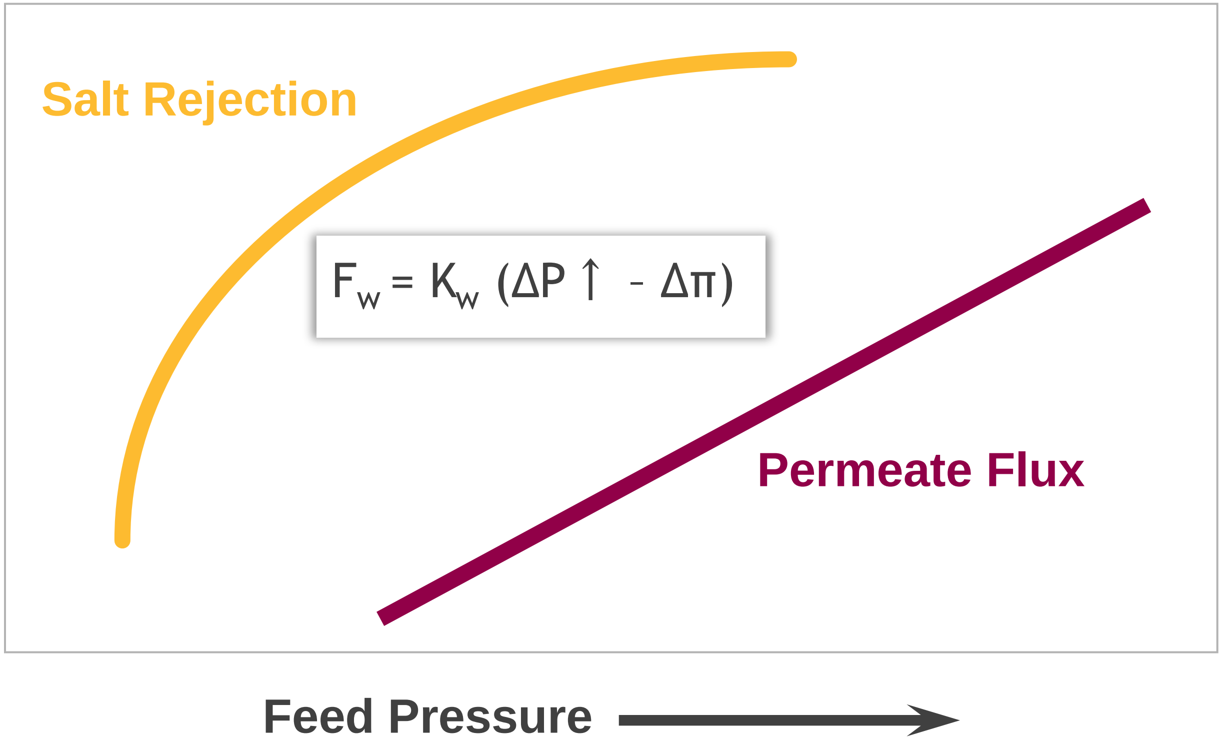
Factors which effect membrane performance

- Feedwater
  - Concentration
  - Temperature
  - Osmotic pressure
  - pH

- Operation parameters
  - Pressure
  - System recovery

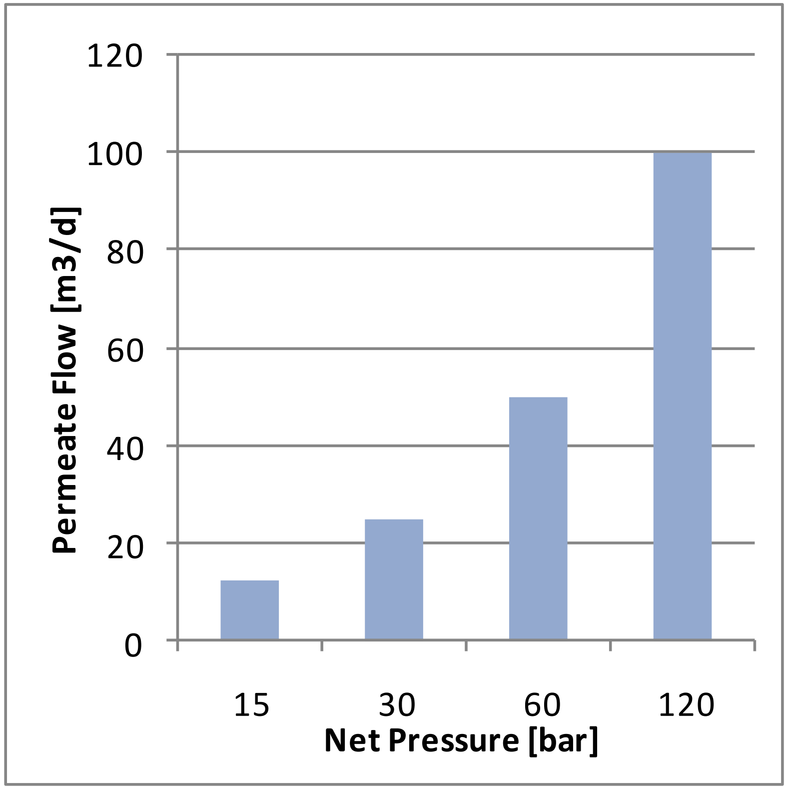
- Concentration Polarization

Affect of feedwater pressure on flux and salt rejection



Assuming temperature, recovery and feed concentration are constant

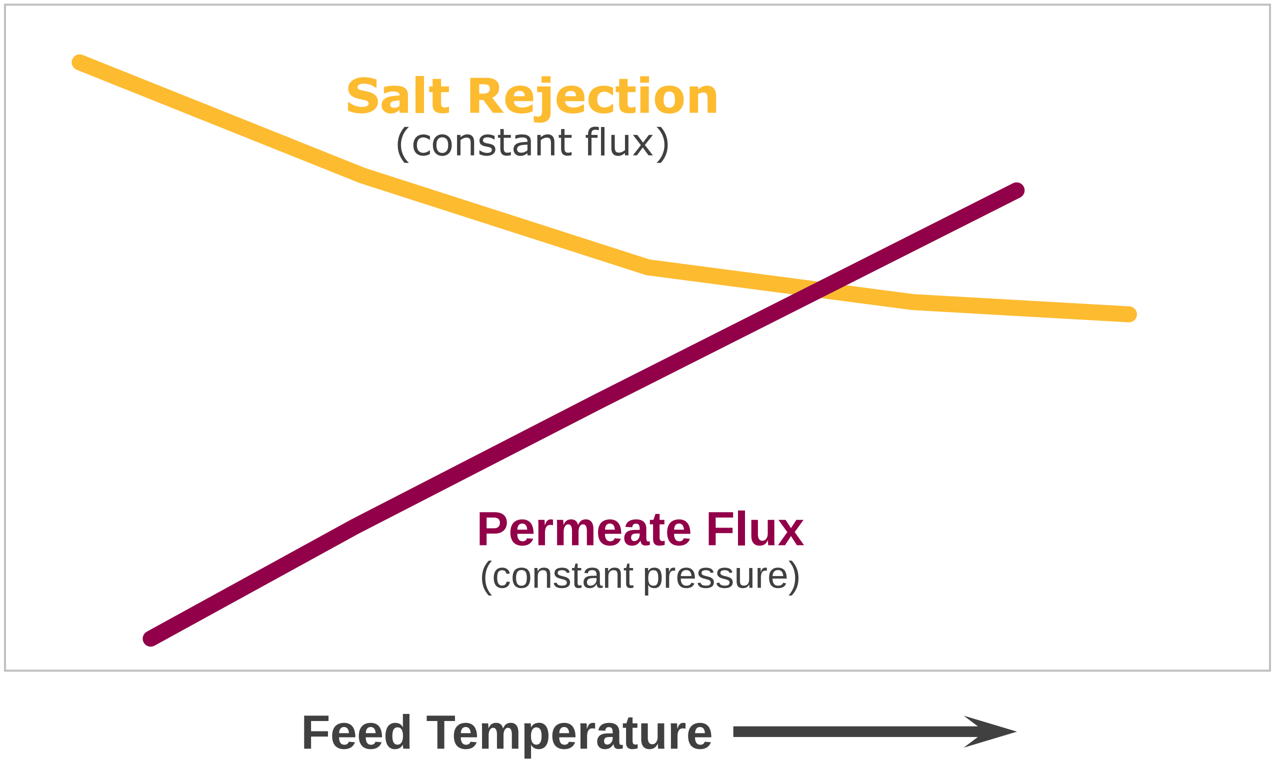
Pressure Affect



- 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

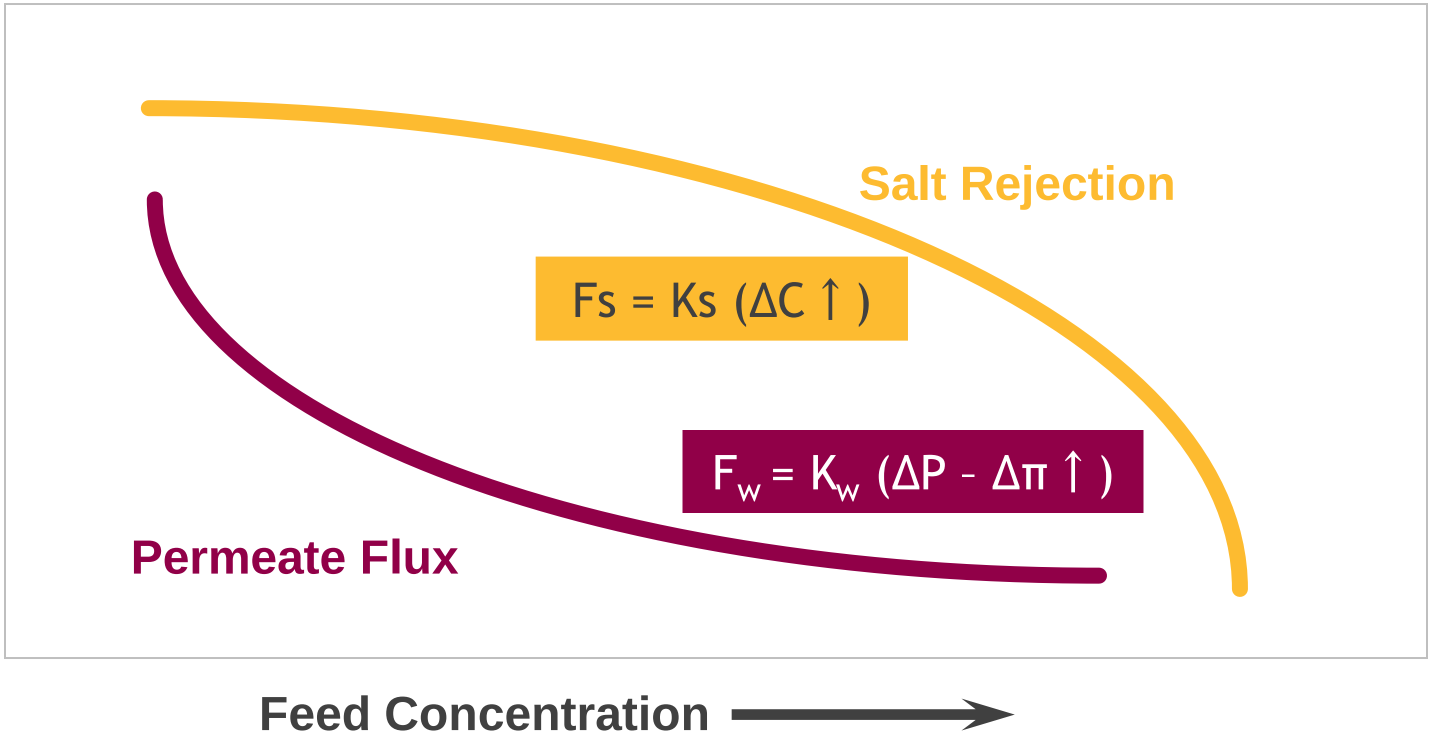
Permeate flow

- 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 1ºC the permeate flow will increase ~ 3%

Salt passage

- Rule of Thumb: salt passage increases 6% for 1ºC 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

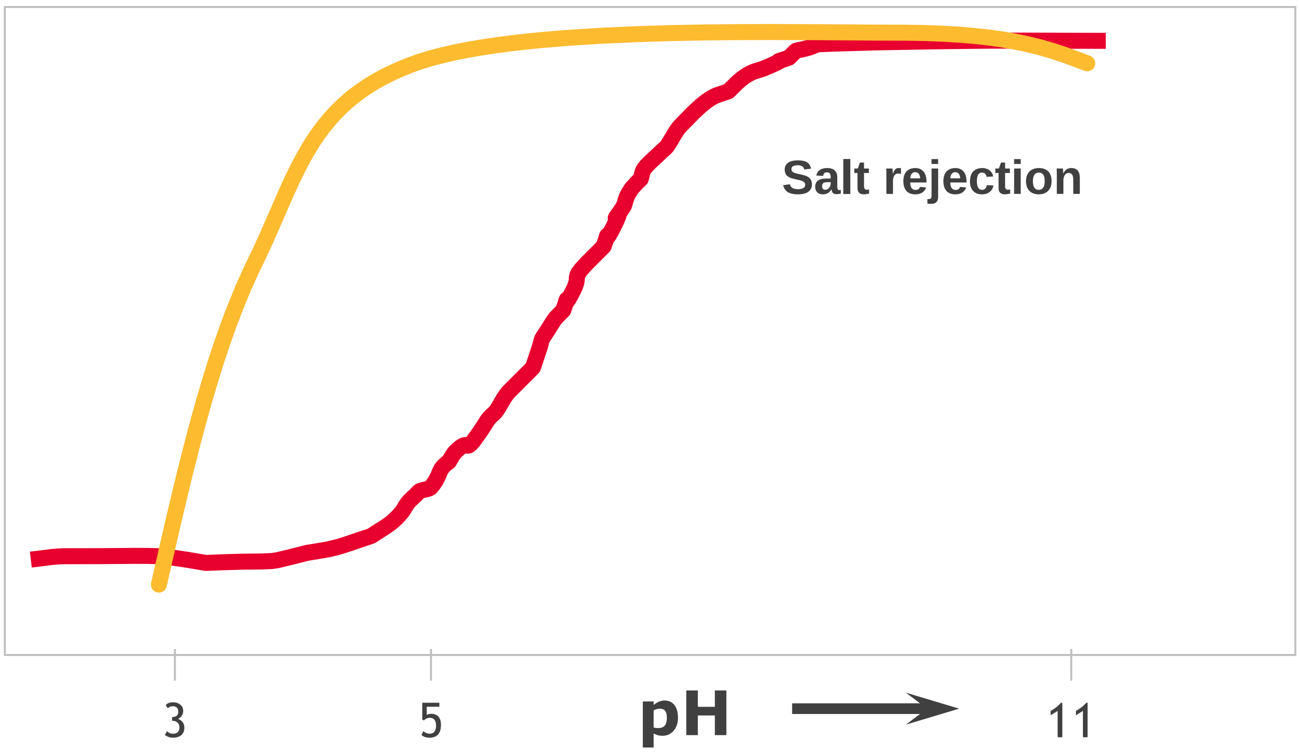
Salt concentration affect

- 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.

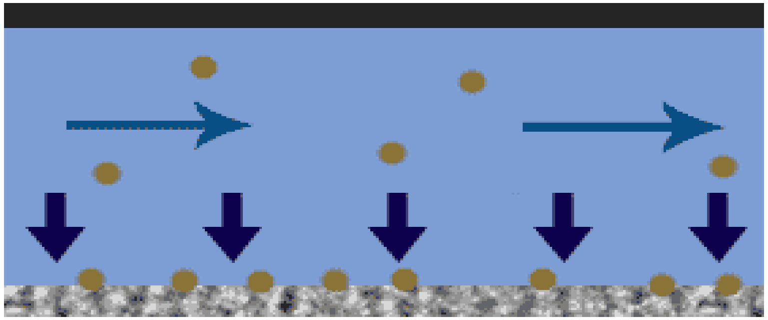
- Salt concentration affect on permeate quality
  - Overall water quality is lower for two reasons, higher rate of salt passage combined with less permeate water.

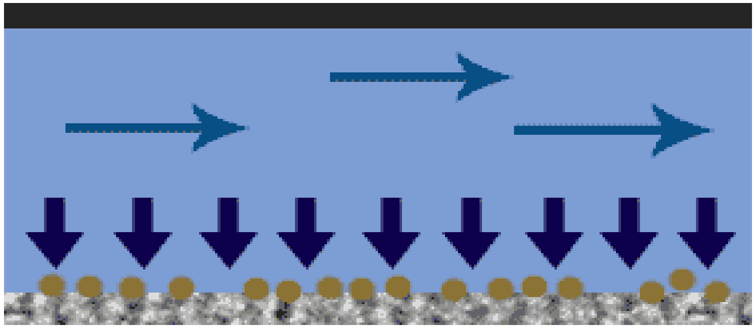
pH influence on salt rejection



Assuming temperature, feed pressure and concentration are constant

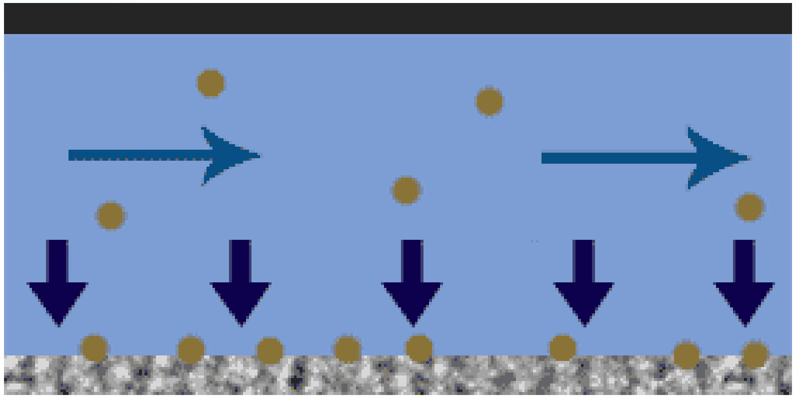
Boundary layer

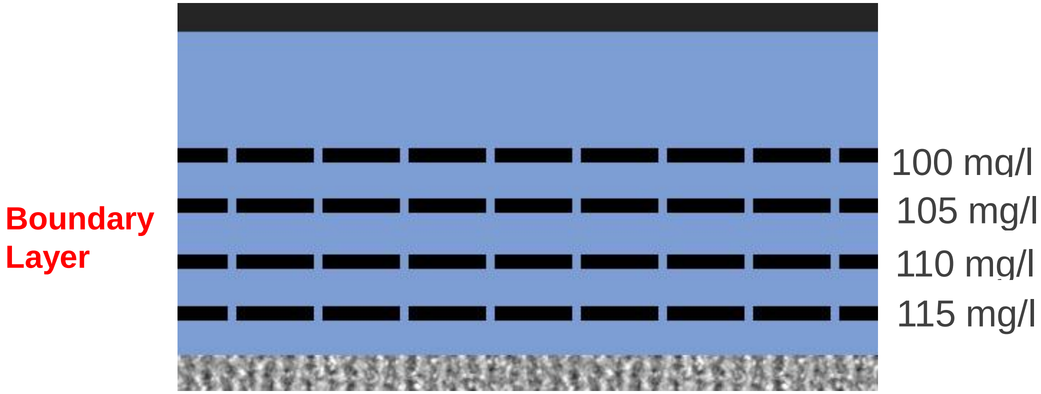




- Water near the membrane surface has little to no cross flow
- Creates an area for particulates & colloids to collect and foul the membrane.
- Water flux through the membrane helps hold foulants in place.

Concentration polarization

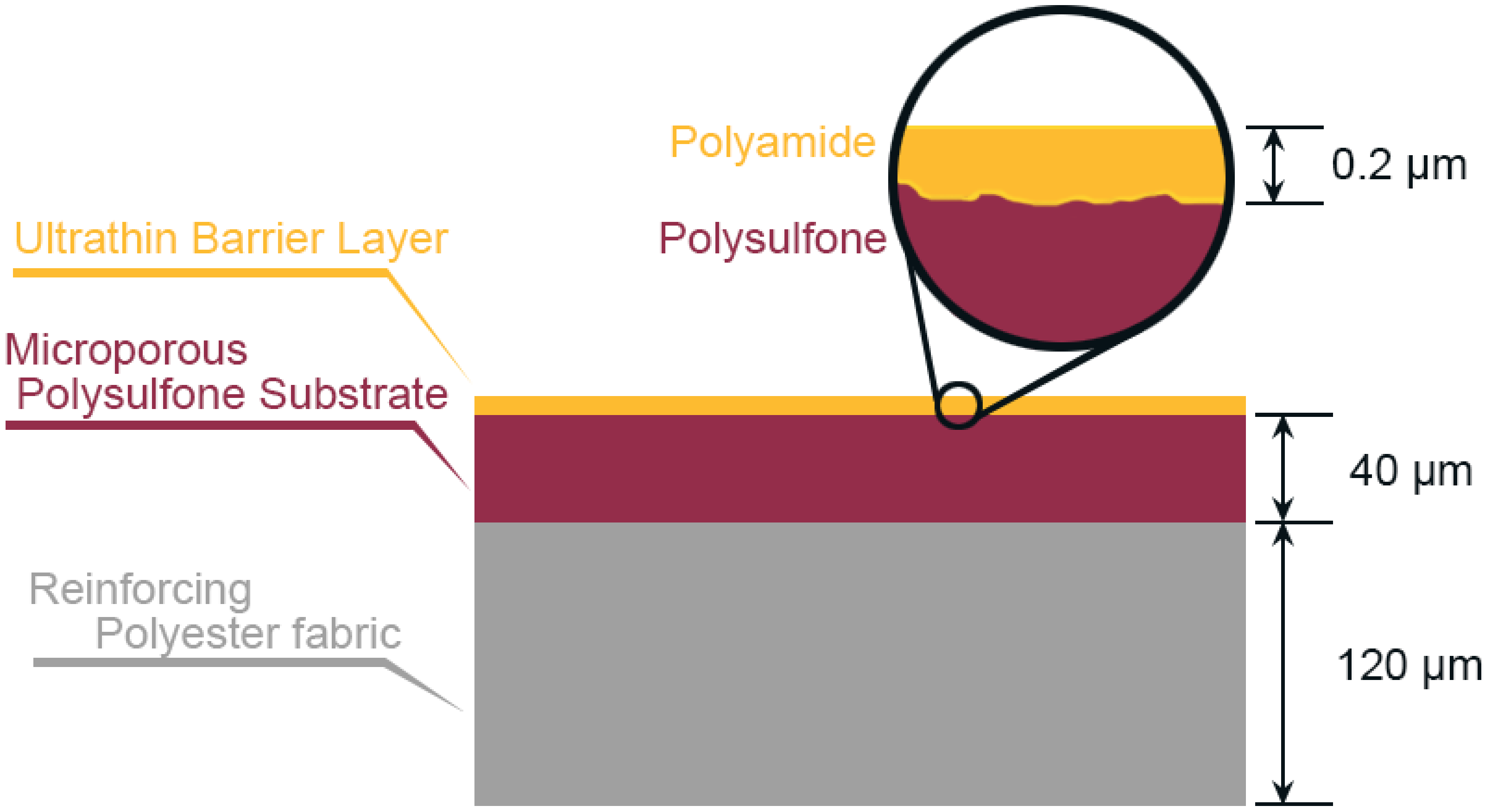




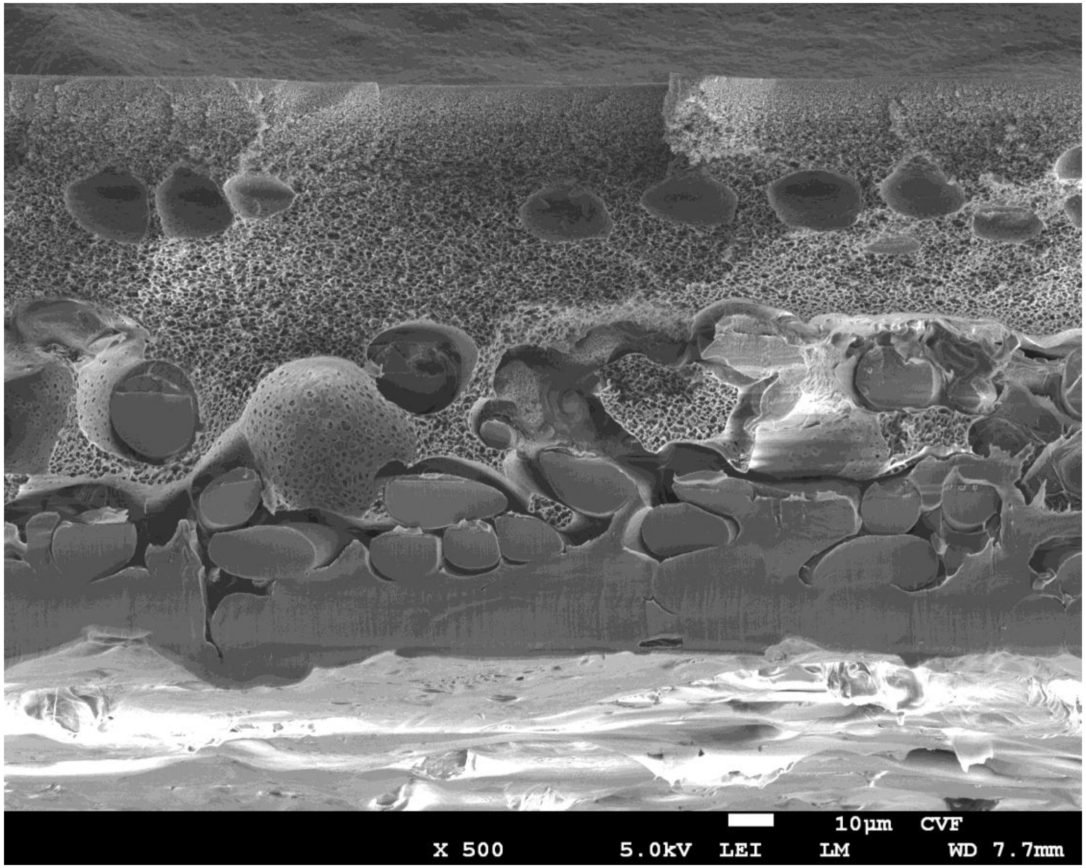
- Concentration polarization is a function of the boundary layer.
- It results in an increased salt concentration at the membrane surface.
- The higher the flux rate through the membrane the higher the salt concentration at the membrane surface.
- Typically the TDS is 13–20% higher than the concentration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

Thin Film Composite Membranes
Spiral Wound Elements

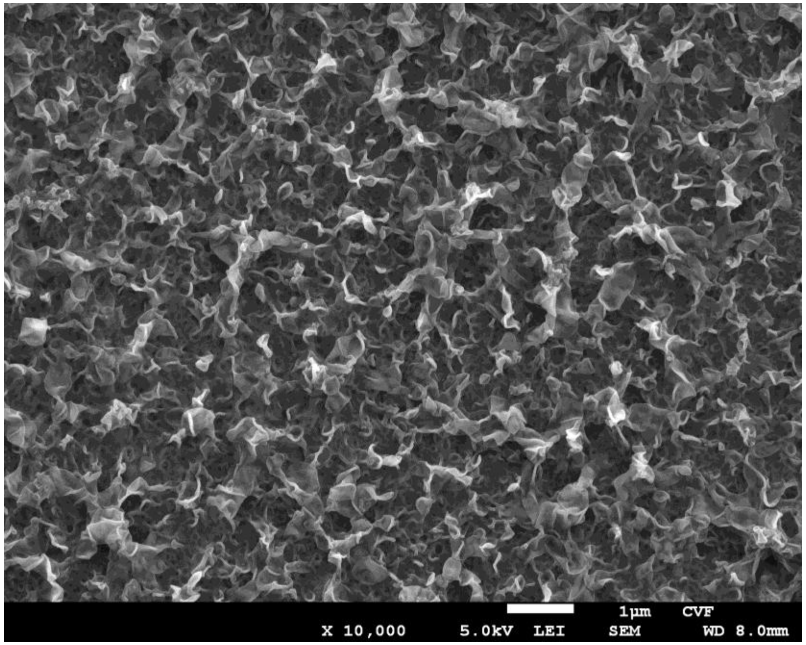
Cross-section of thin film composite membrane



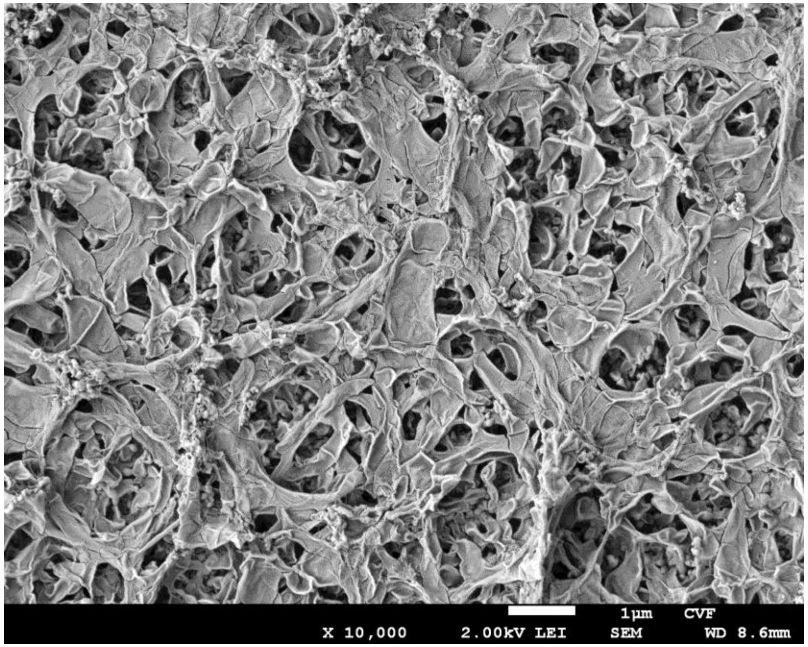
FILMTEC™ membrane cross-section (SEM image)



Surface of barrier layer of FT30 (SEM image)

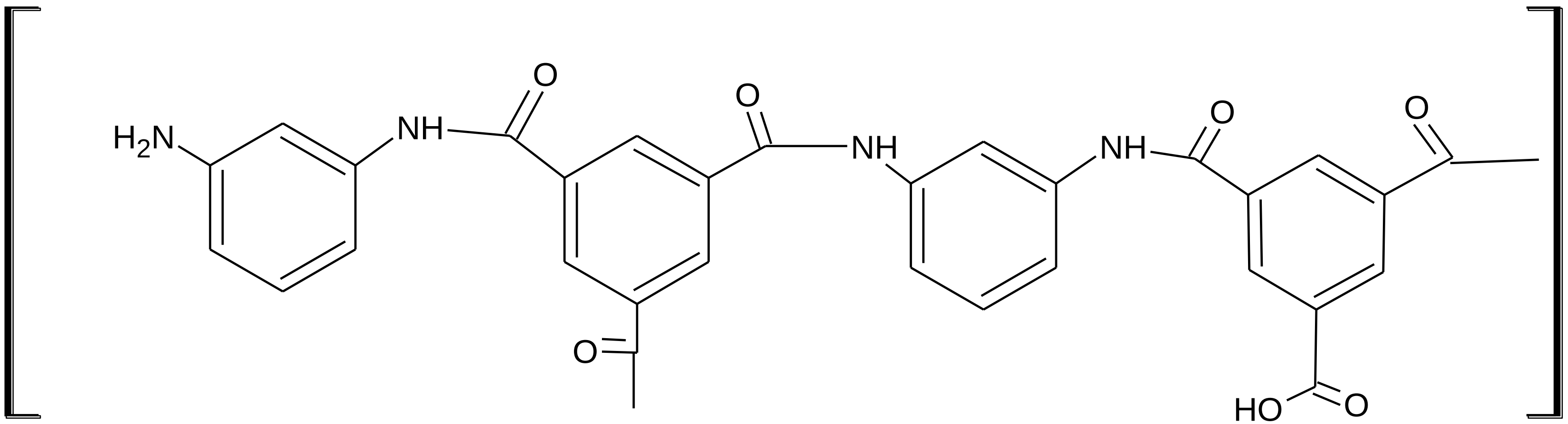


BW30 Membrane



XLE Membrane

Flat sheet membrane FT30 chemistry



Free amine **Carboxylate**

Aromatic Polyamide Barrier Layer

Factors affecting membranes solute rejection

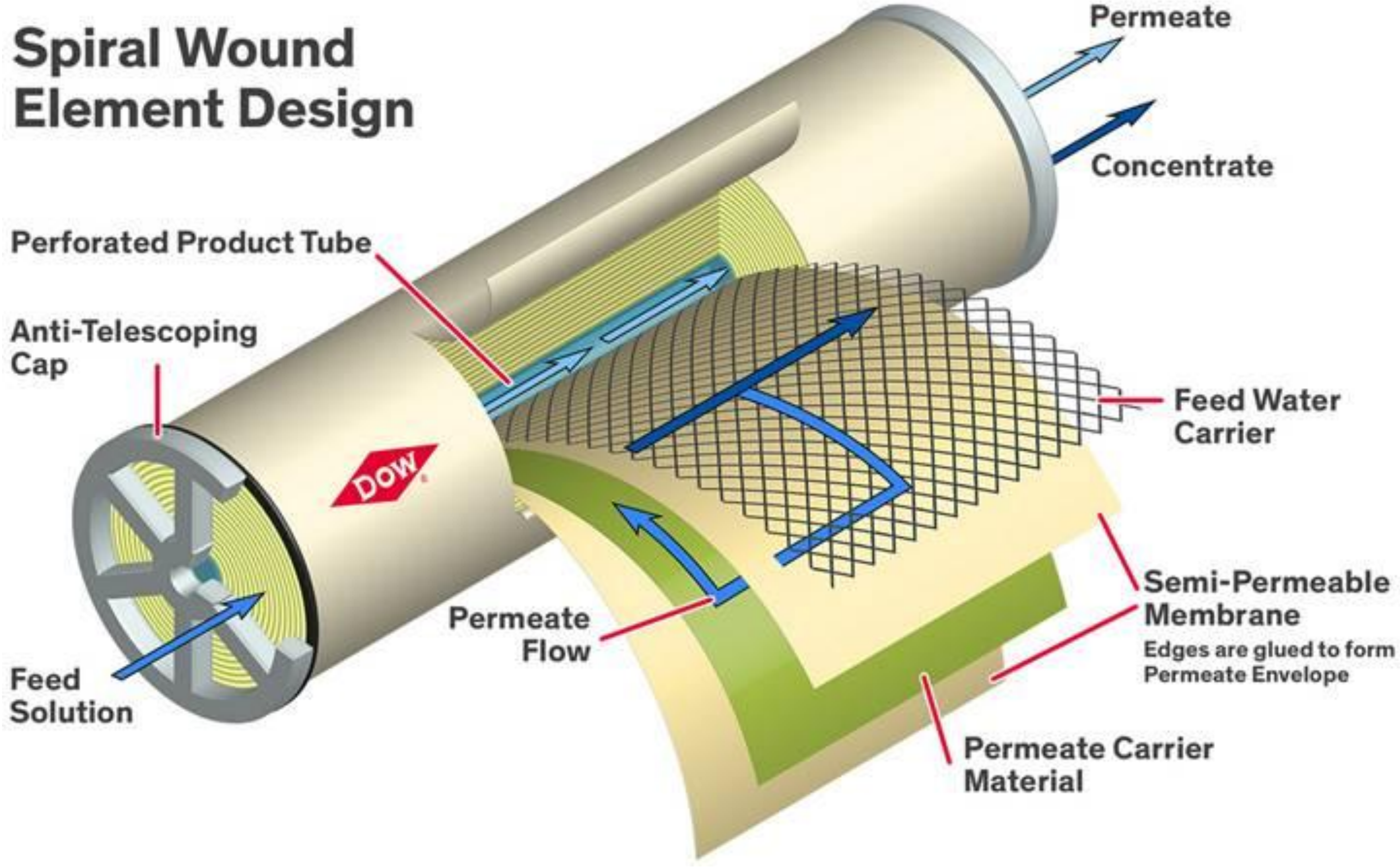
Membrane type/condition:

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

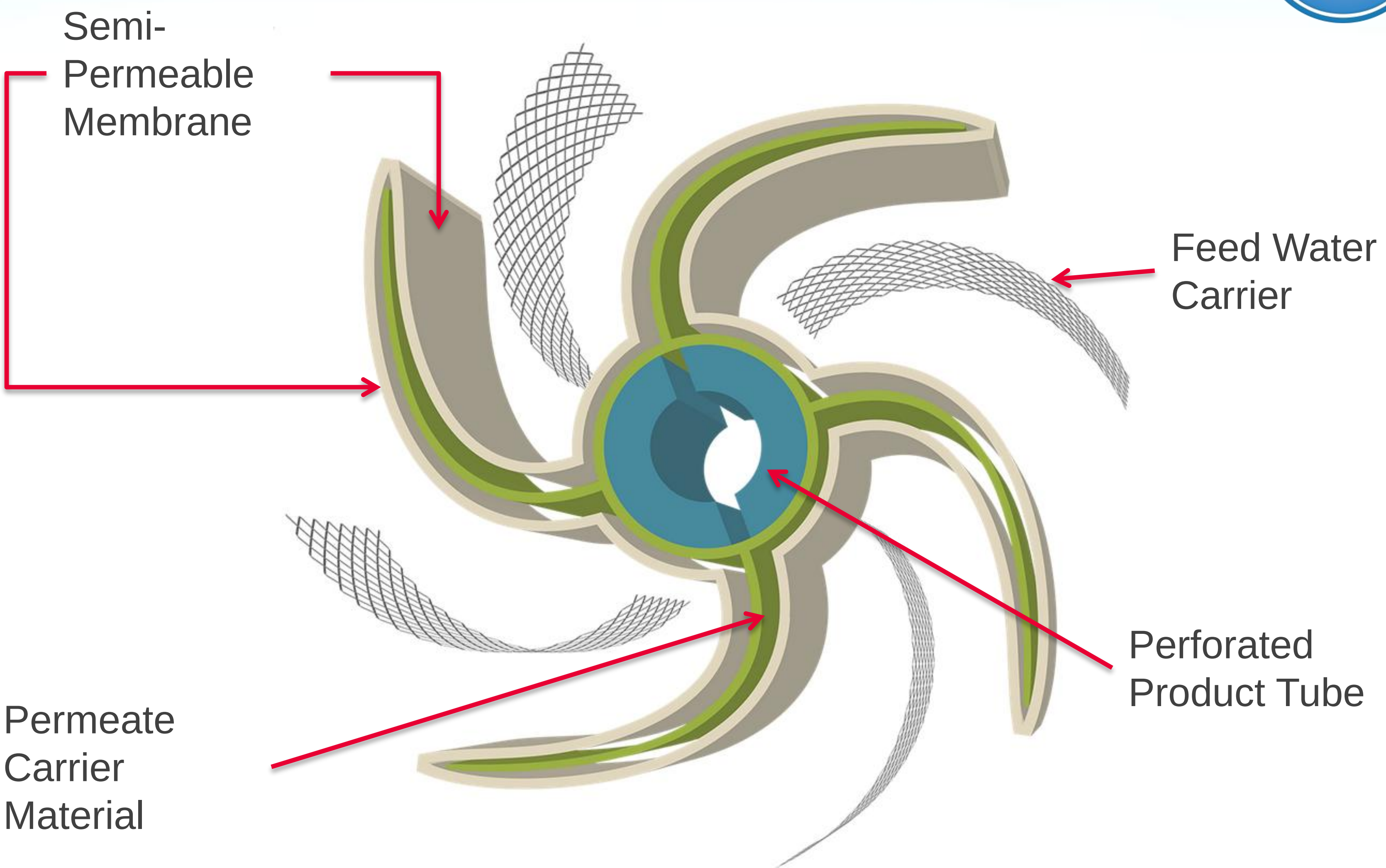
Solute characteristics

- 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?

WATER & PROCESS SOLUTIONS

WATER ACADEMY

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

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

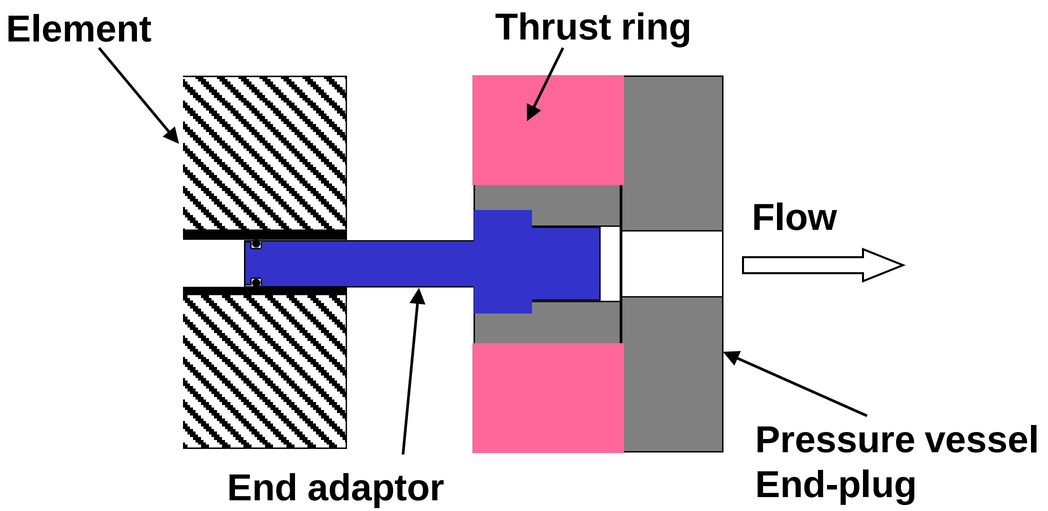
Cleaning and Lubrication of PVs

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

Concentrate side



Example for thrust ring

<u>Alternative:</u> 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

Loading
-1st 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**

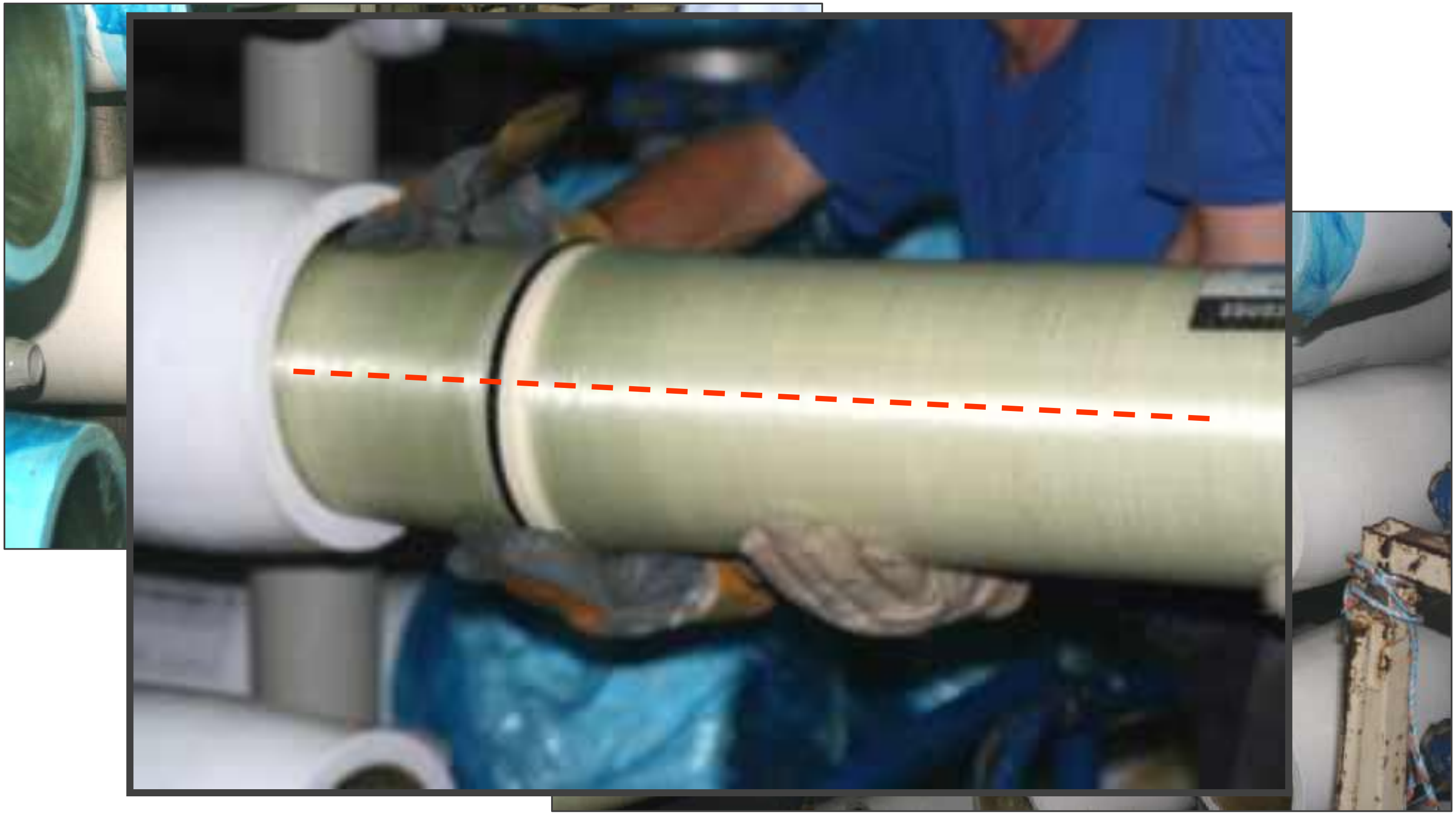
Other lubricants may cause performance issues!

Brine seal check and lubrication

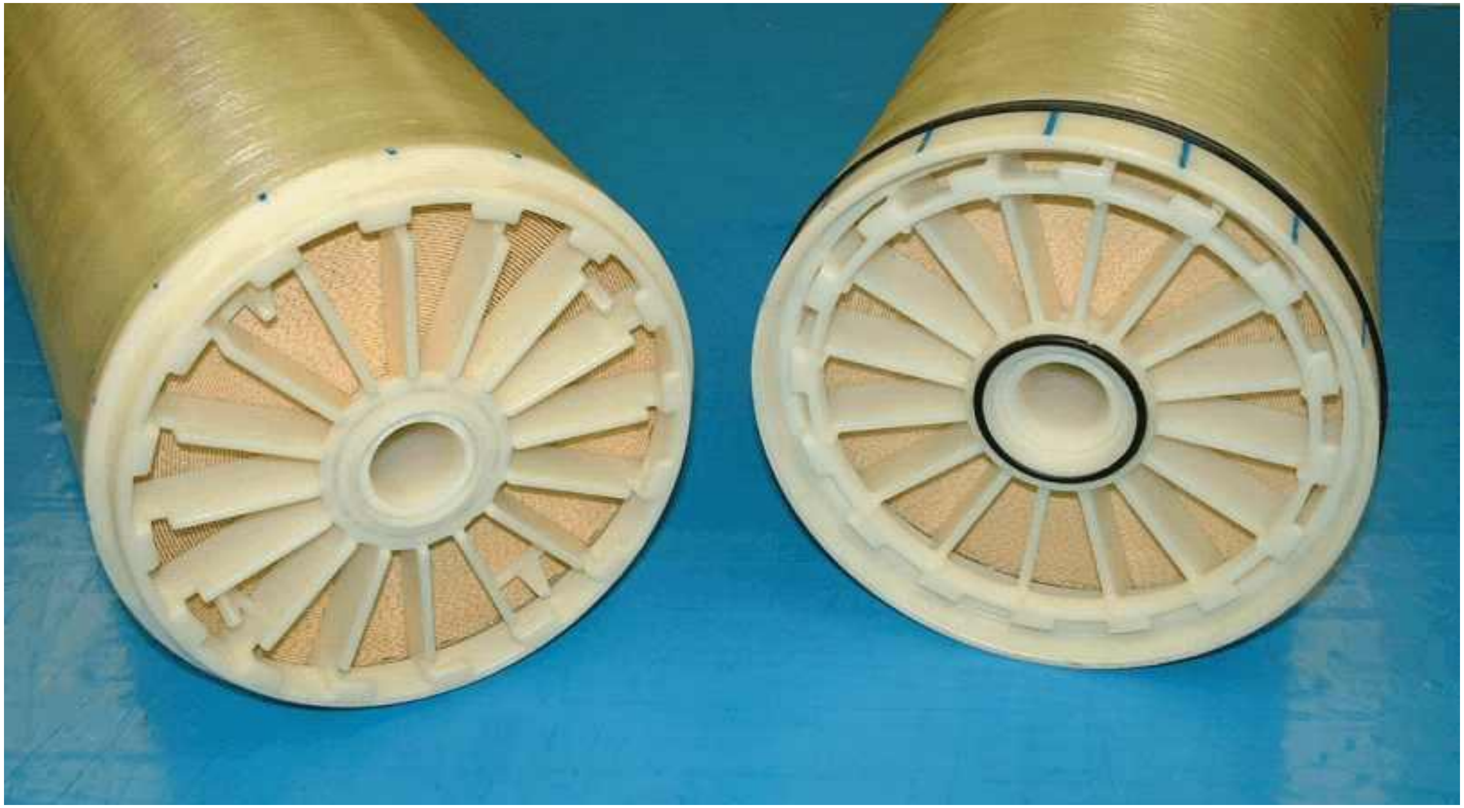
- glycerin/water (50/50) solution
- food grade glycerin
- Dow Corning® 111

Adding elements

Always support the element to keep it horizontal!



iLEC™ Elements



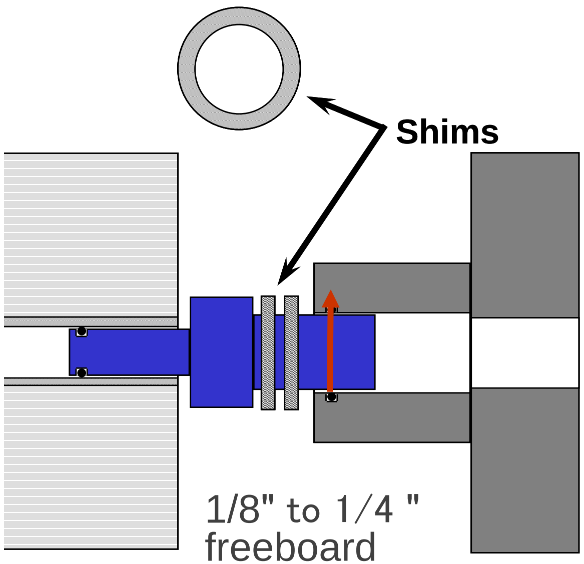
See Training video on

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

Keyword "iLEC"

Shimming

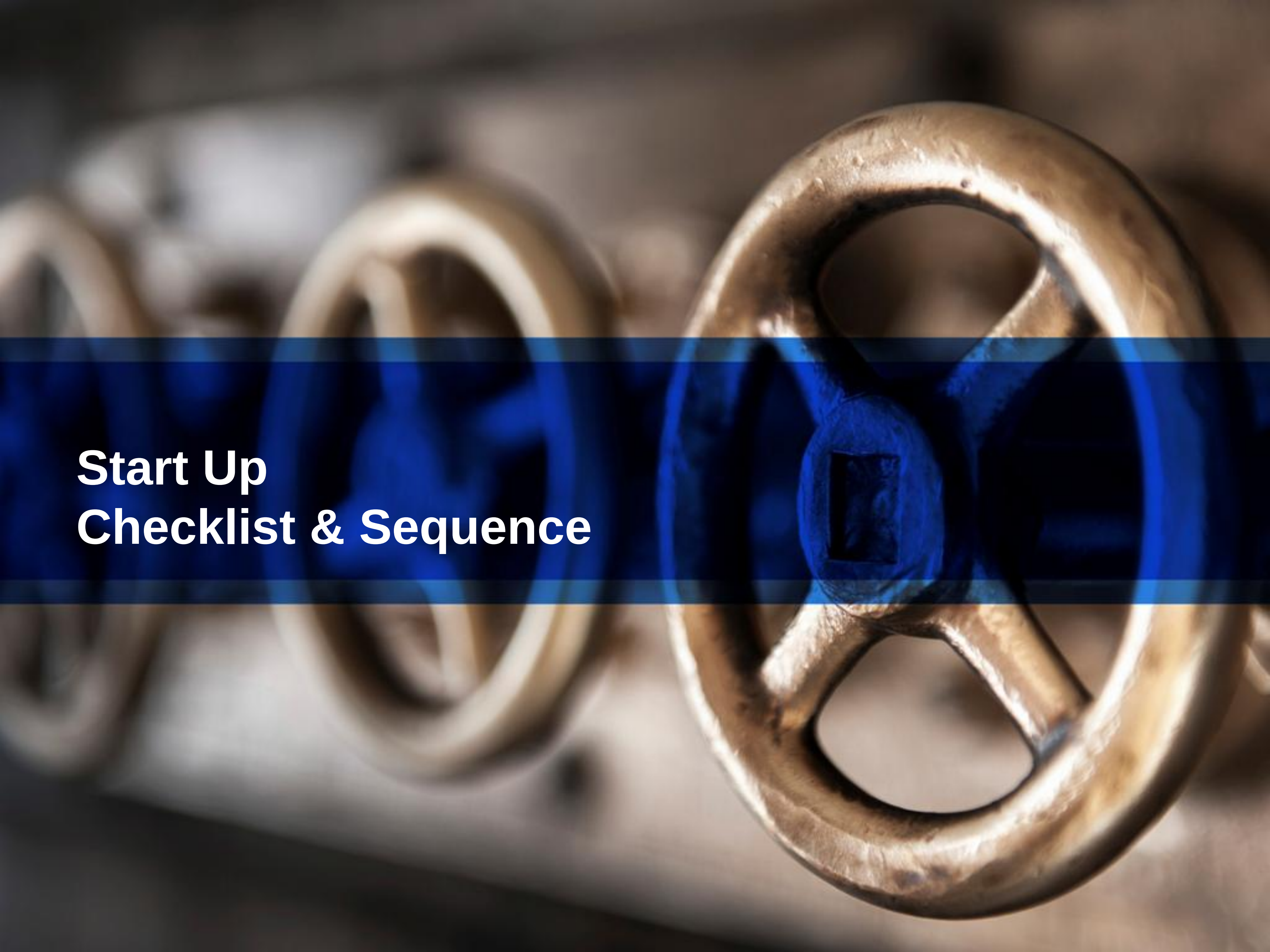
Feed end



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


Start Up
Checklist & Sequence

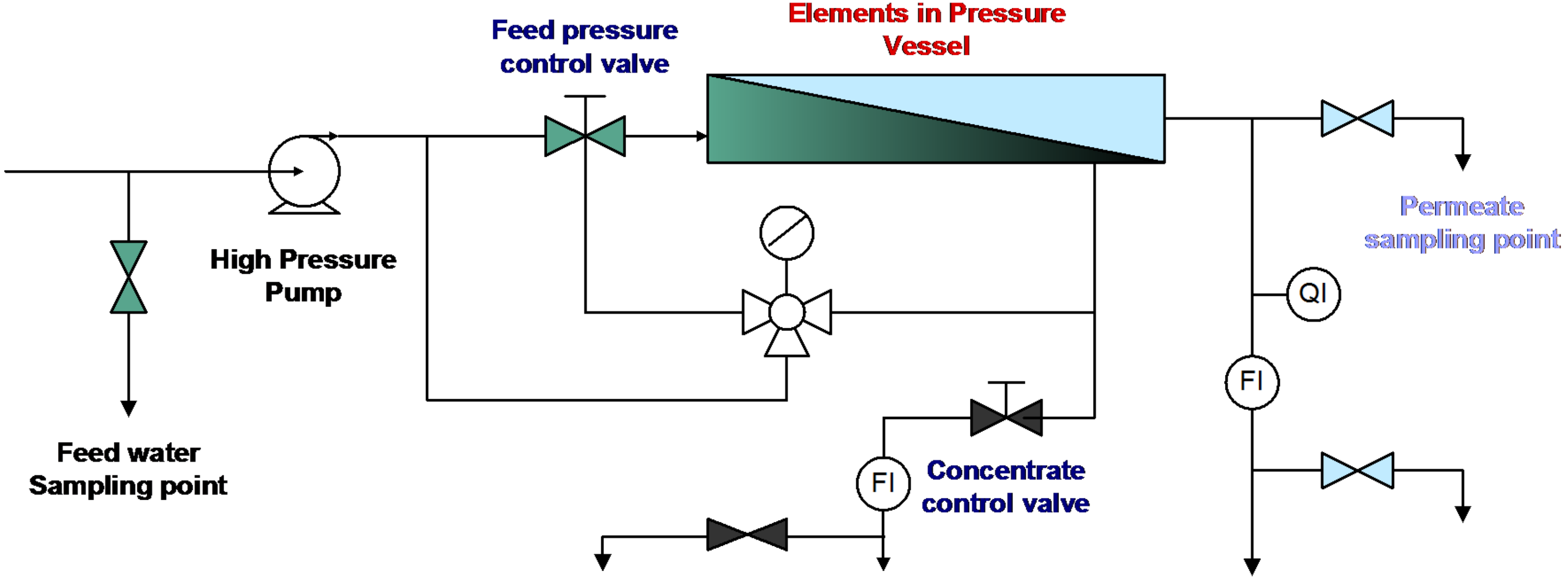
Checklist for start-up (1/2)

- ✓ 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

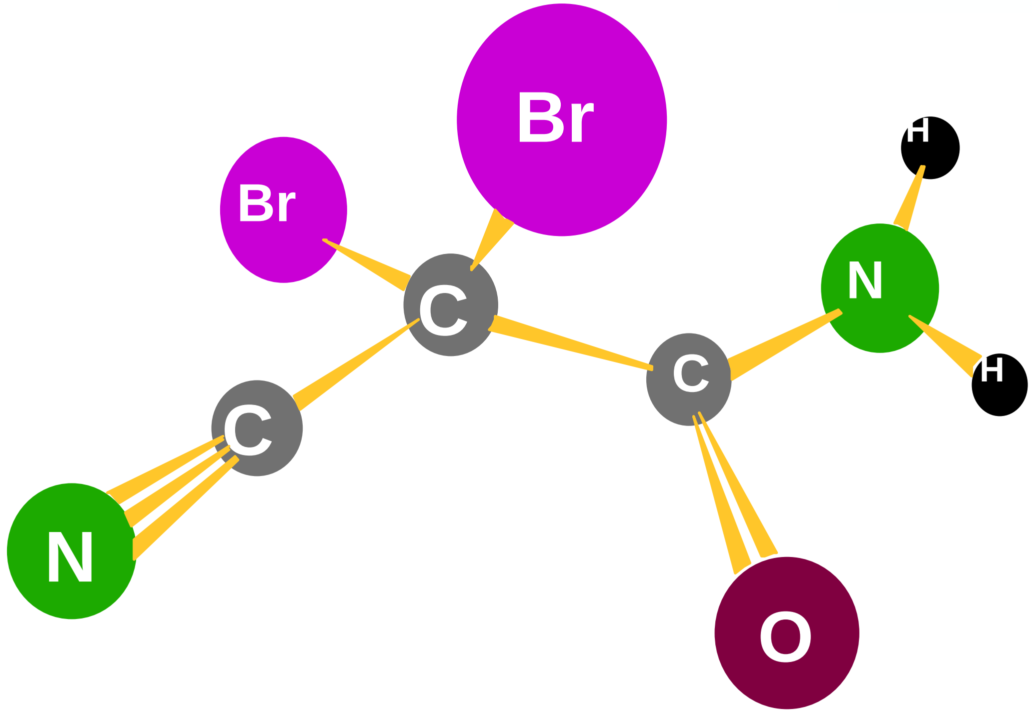
Reasons for Shut-down

- 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° 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!

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http://www.dowwaterandprocess.com/

WATER & PROCESS SOLUTIONS

WATER ACADEMY

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

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
1-3 pm CDT

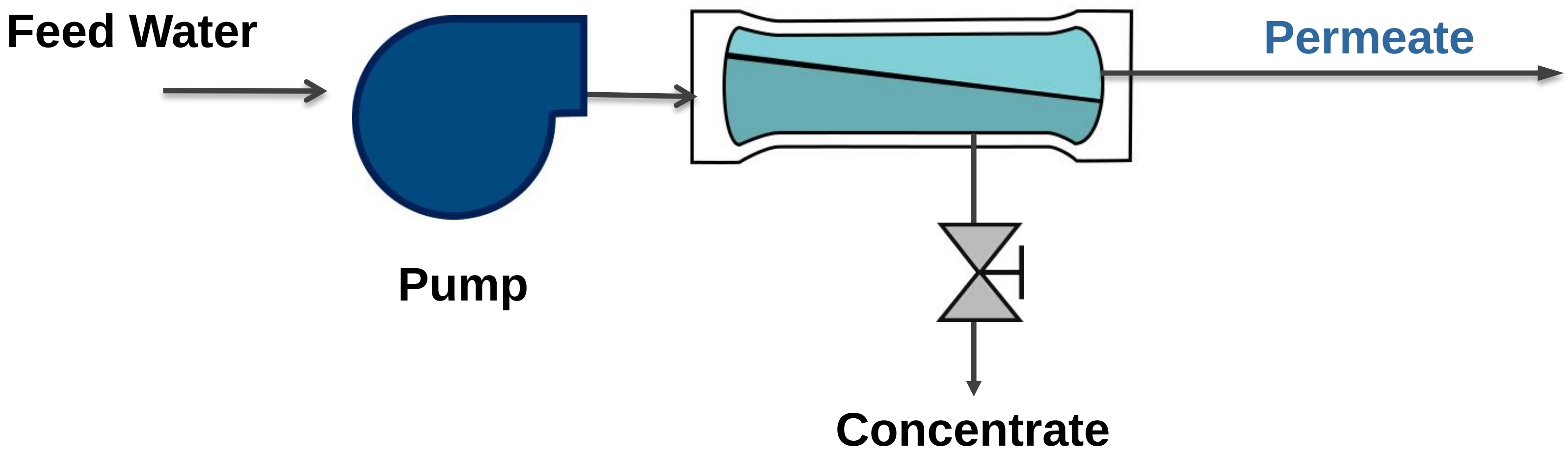
Advanced RO System Design with ROSA

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

Overview

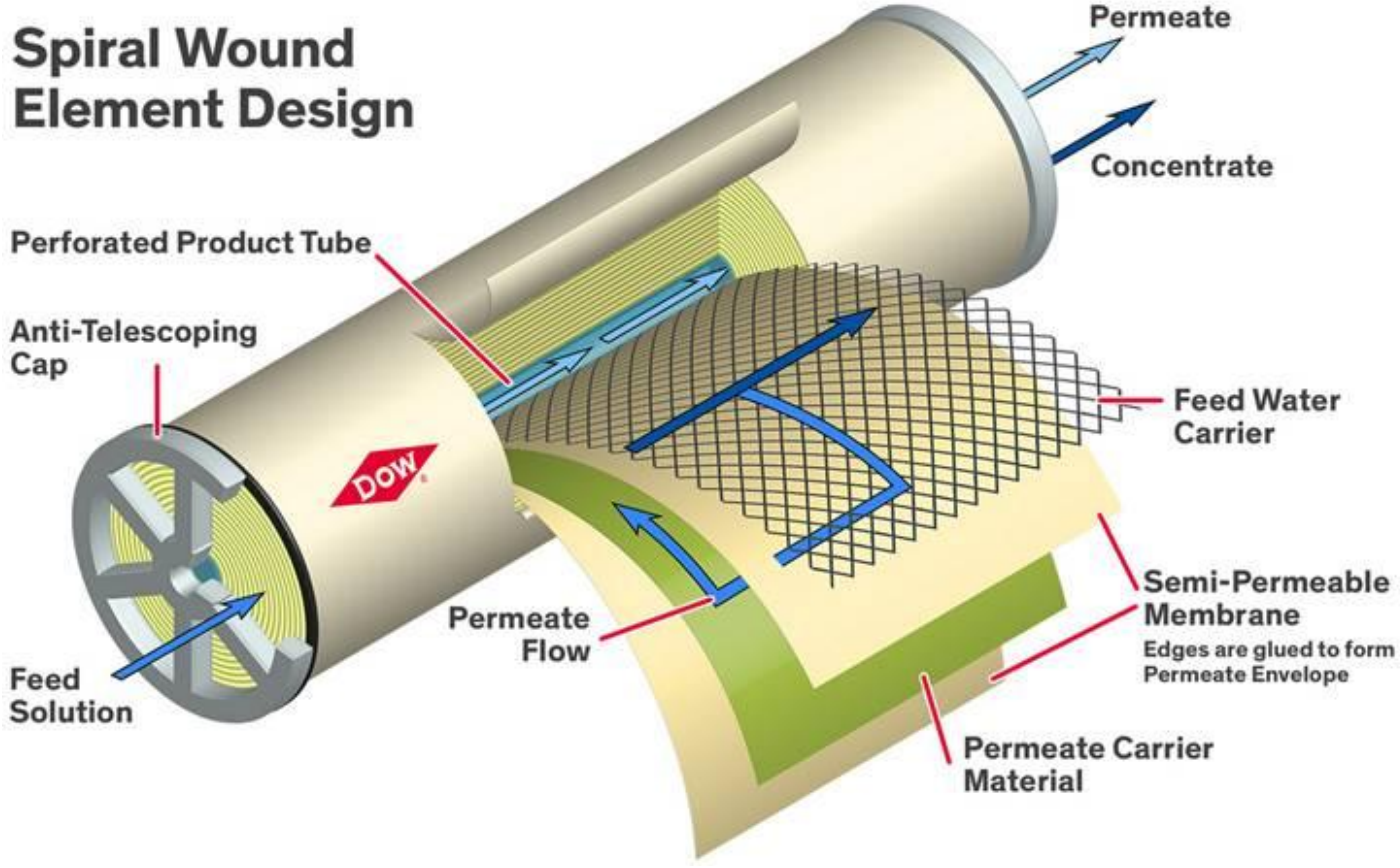
1. Scope of system design
2. System configuration types
3. System design guidelines
4. Ten steps to design a membrane system

Simplified RO system



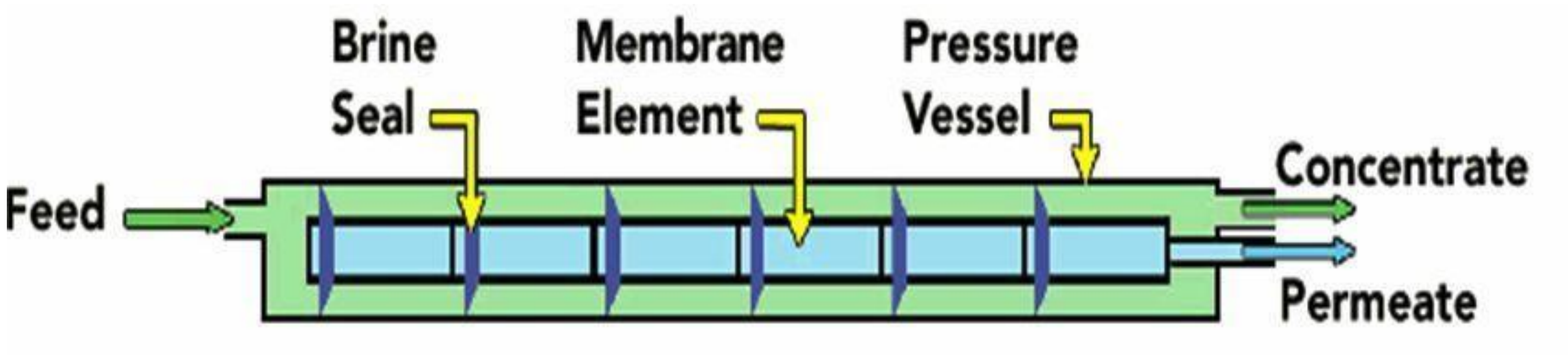
100 to 600 psi (7 to 42 bar) -brackish water
800 to 1,200 psi (55 to 83 bar) -seawater

Spiral wound RO membrane element



Main components of a membrane system

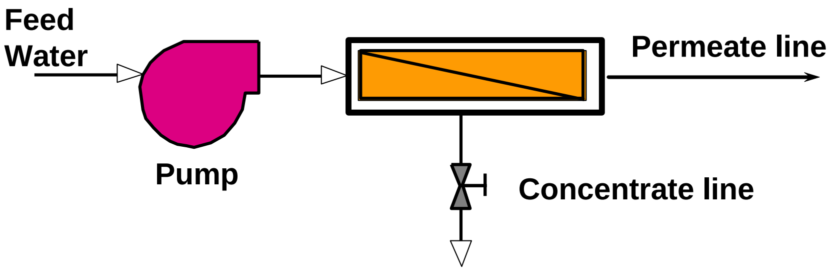
Serial arrangement of membrane elements in a pressure vessel



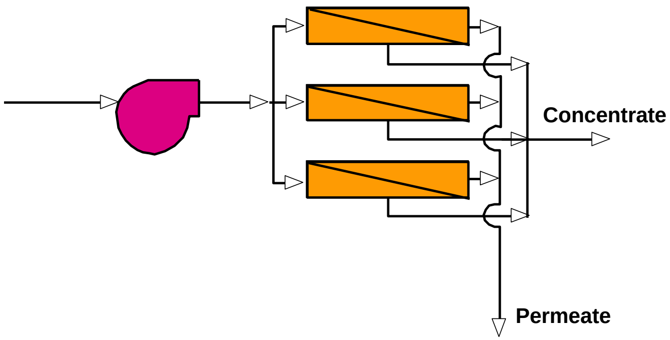
DOW FILMTEC™
RO Element

System configuration types

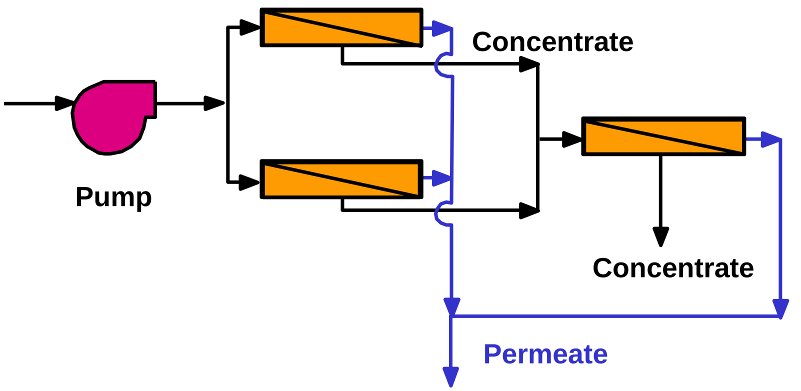
Single Vessel



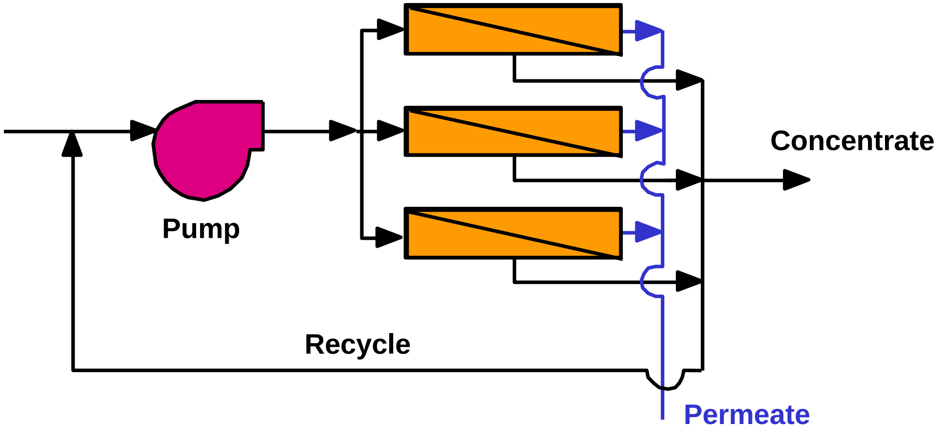
Single Stage



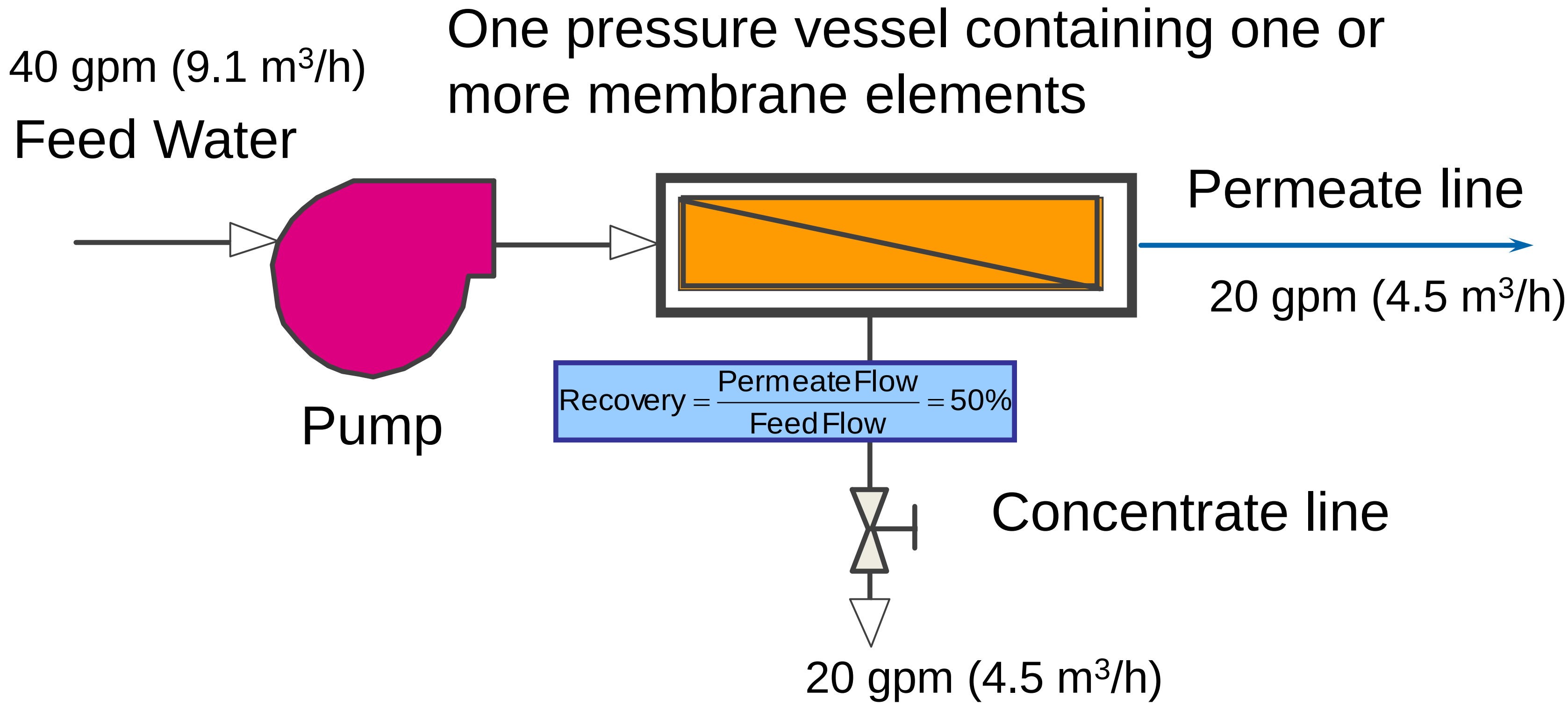
Multistage



Concentrate Recycle



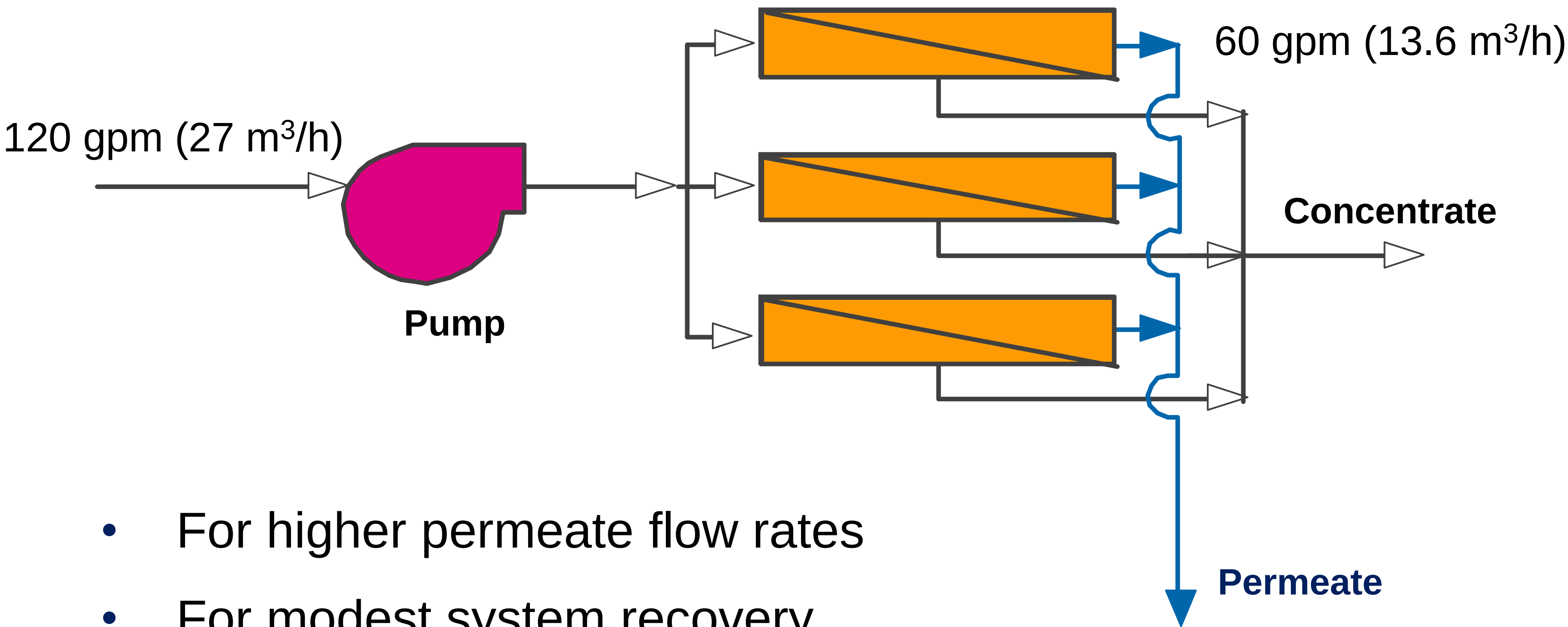
Configuration- single vessel system



- For low flow rate
- For low system recovery

Configuration- single stage system

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

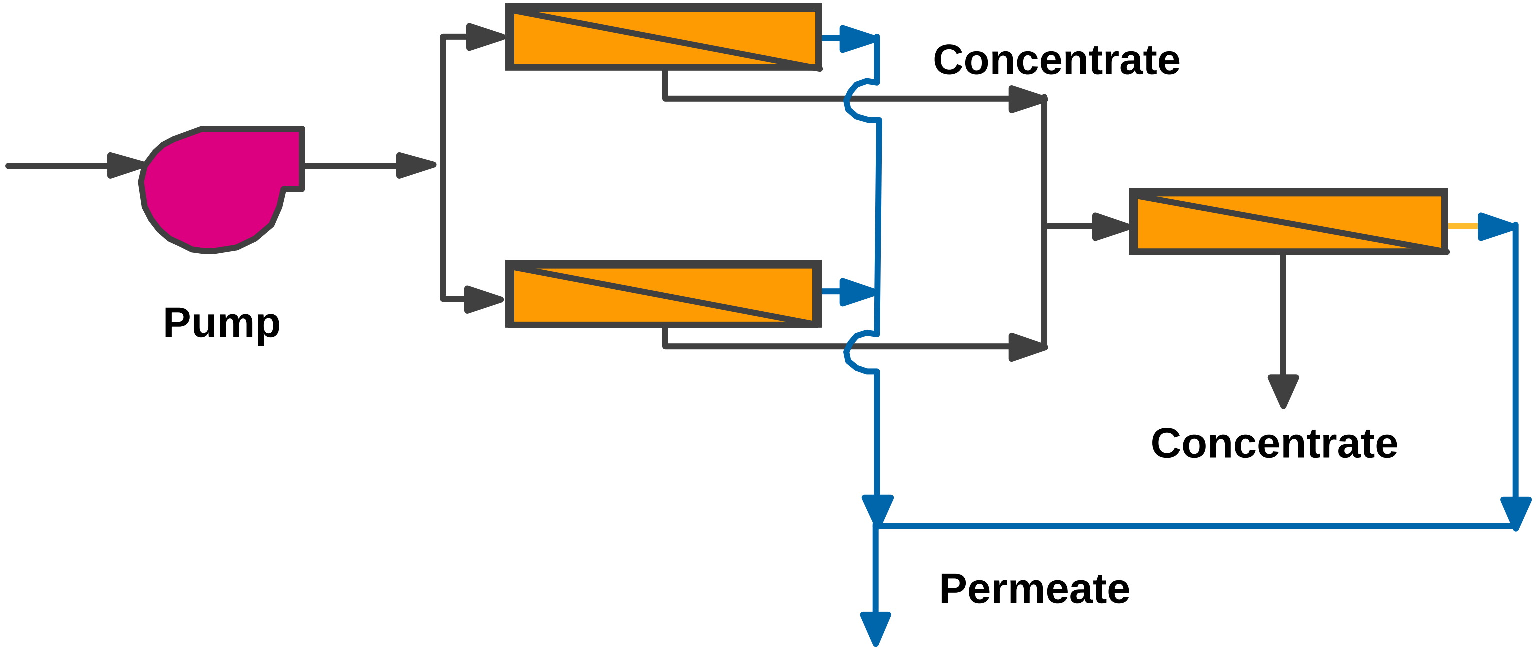


- For higher permeate flow rates
- For modest system recovery
- Typical in seawater desalination

$$\text{Recovery} = \frac{\text{Permeate Flow}}{\text{Feed Flow}} = 50\%$$

Configuration- multi-stage system

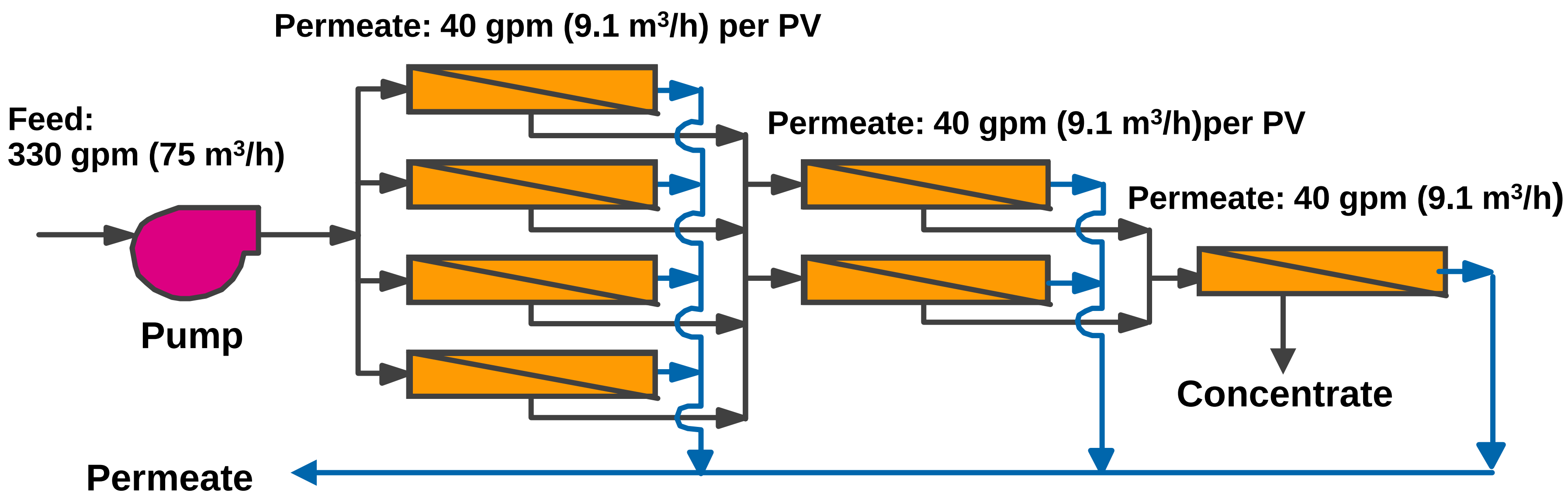
Two-stage system



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

Configuration- multi-stage system

Three-stage system



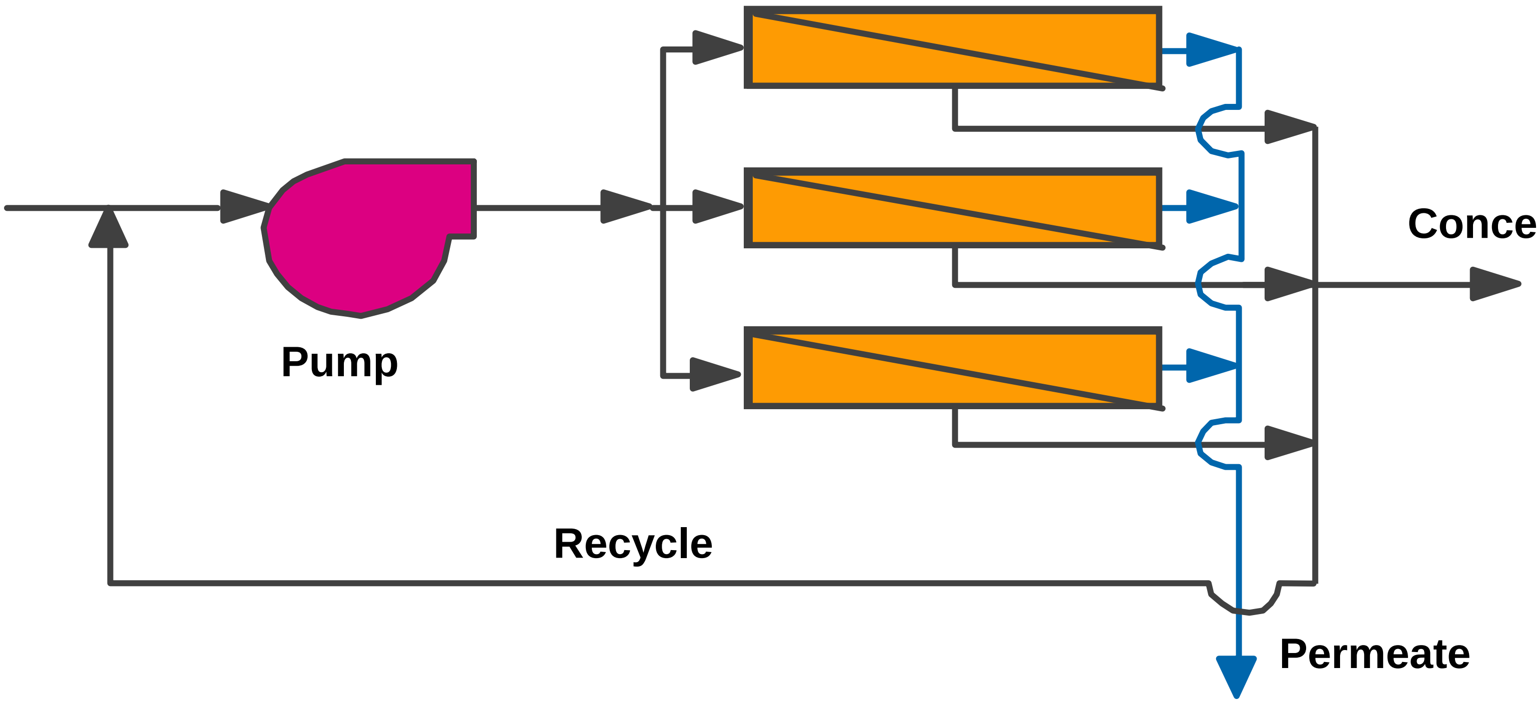
$$\text{Recovery} = \frac{\text{Permeate Flow}}{\text{Feed Flow}} = \frac{160+80+40}{330} > 85\%$$

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

WATER & PROCESS SOLUTIONS

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[1]	Conventional	Dow UF	UF/MF[1]	Conventional	Dow UF	UF/MF[1] 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^2h)	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

[1] 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[1]	Conventional	Dow UF	UF/MF[1]	Conventional	Dow UF	UF/MF[1] or Well	Open Intake
SDI	<1	<3	<2.5	<3	<5	<2.5	<3	<5	<2.5	<3	<5
Active Membrane Area (ft^2)	Maximum permeate flow rate, gpd (m^3/d)										
365	10.200 (38)	8.500 (32)	8.500 (32)	7.200 (27)	6.600 (25)	6.300 (24)	5.900 (22)	5.200 (20)			
380	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)
400	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)
440	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)

[1] 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[1]	Conventional	Dow UF	UF/MF[1]	Conventional	Dow UF	UF/MF[1] or Well	Conventional
SDI	<1	<3	<2.5	<3	<5	<2.5	<3	<5	<3		<5
Element type	Minimum concentrate flow rate[2], gpm (m^3/h)										
Brackish water (365 ft^2)	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^2)	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)

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

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

[1] 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^3/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^3/h (10 gpm)
  - 8.0-inch > 2.3 m^3/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^3/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 lmh) 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

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

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

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

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

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

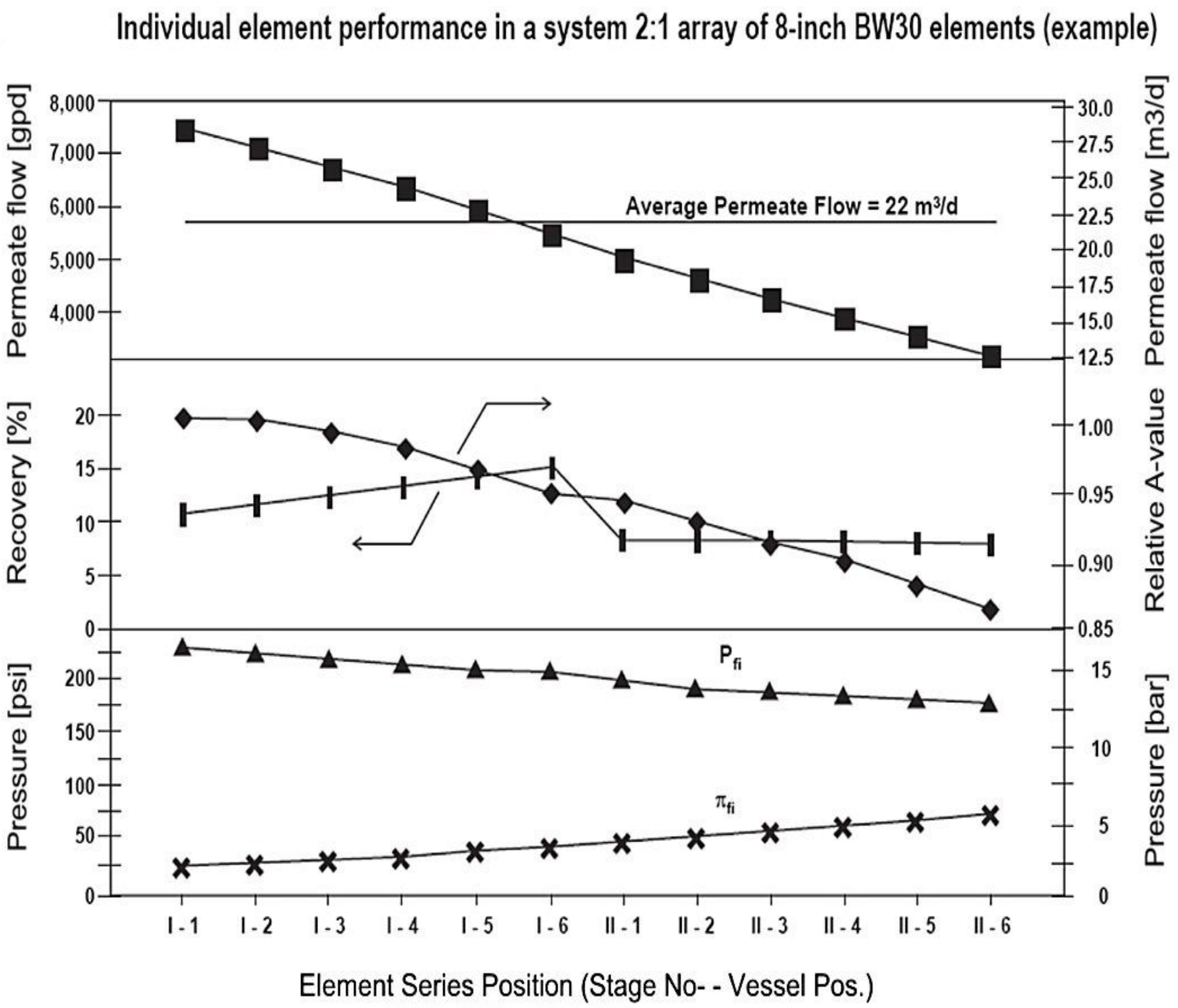
Ten steps to design a membrane system

- 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



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/

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
1-3 pm CDT

Advanced RO System Design with ROSA

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

WATER & PROCESS SOLUTIONS

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

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

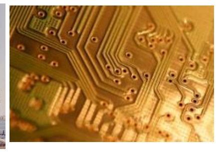
WATER ACADEMY

VARIOUS APPLICATIONS

Industrial/ Power/UPW

1st & 2nd pass





Wastewater Reuse

1st & 2nd pass

Irrigation

1st pass

Municipal Potable

1st pass

SWRO

1st & 2nd Pass

VARIOUS FEED WATER SOURCES

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

Increasing Fouling Potential

Global Market

Global Project Development

VARIOUS QUALITY REQUIREMENTS

- B < 0. 3-1 mg/l
- Br < 0.1 mg/l
- TOC < 10 ppb
- NO_3 < 0.5 -35 mg/l
- NH_4 < 0.5 mg/l
- SiO_2 < 10 ppb
- Hardness 0.5 mg/l - 200 mg/l $CaCO_3$
- TDS: 0.1 mg/l - 500 mg/l

Regional Preferences

Regional Regulations

Strong Regional Variations

(TDS/Temp)

Market Segment Nuances for RO Design

Municipal	Industrial
• Medium to large size plants	• Small to medium size plants
• Wide permeate quality targets	• Narrow permeate quality targets
• Total cost of water is most critical	• System reliability is most critical
↓	↓
• Greater latitude in system design	• Narrow latitude in system design
• Larger selection of RO elements	• 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	Design Considerations
Temperature	Min T = Max P; Max T = Max TDS & Flux
pH	Rejection; Rejection of spec. ions; Scaling
Silt Density Index	Fouling potential; Pretreatment
Turbidity	Fouling potential; Pretreatment
Salinity	Membrane choice; Recovery; Pressure

System Variables

System Variables	Design Considerations
Element Flux	Number of RO elements and vessels
Element Feed Flow	Differential pressure; Number of vessels
Differential Pressure	Num. of elements/vessel; Spacer; Life
Element Recovery	System recovery; Salinity; flux balance
Operating Pressure	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 feed pressure
↑	NF270	↓
	NF90	
	XLE	
	LE	
	XFRLE	
	HRLE	
	BW30 / TW30	
	ECO	
	BW30XFR	
	BW30HR	
	SEAMAXX	
	SW30ULE	
	SW30XLE	
	SW30HR	
	SW30HRLE	
	SW30XHR	
Lower Salt passage		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

WATER ACADEMY

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

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

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

Calculate number of vessels of first stage NV(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 2nd 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

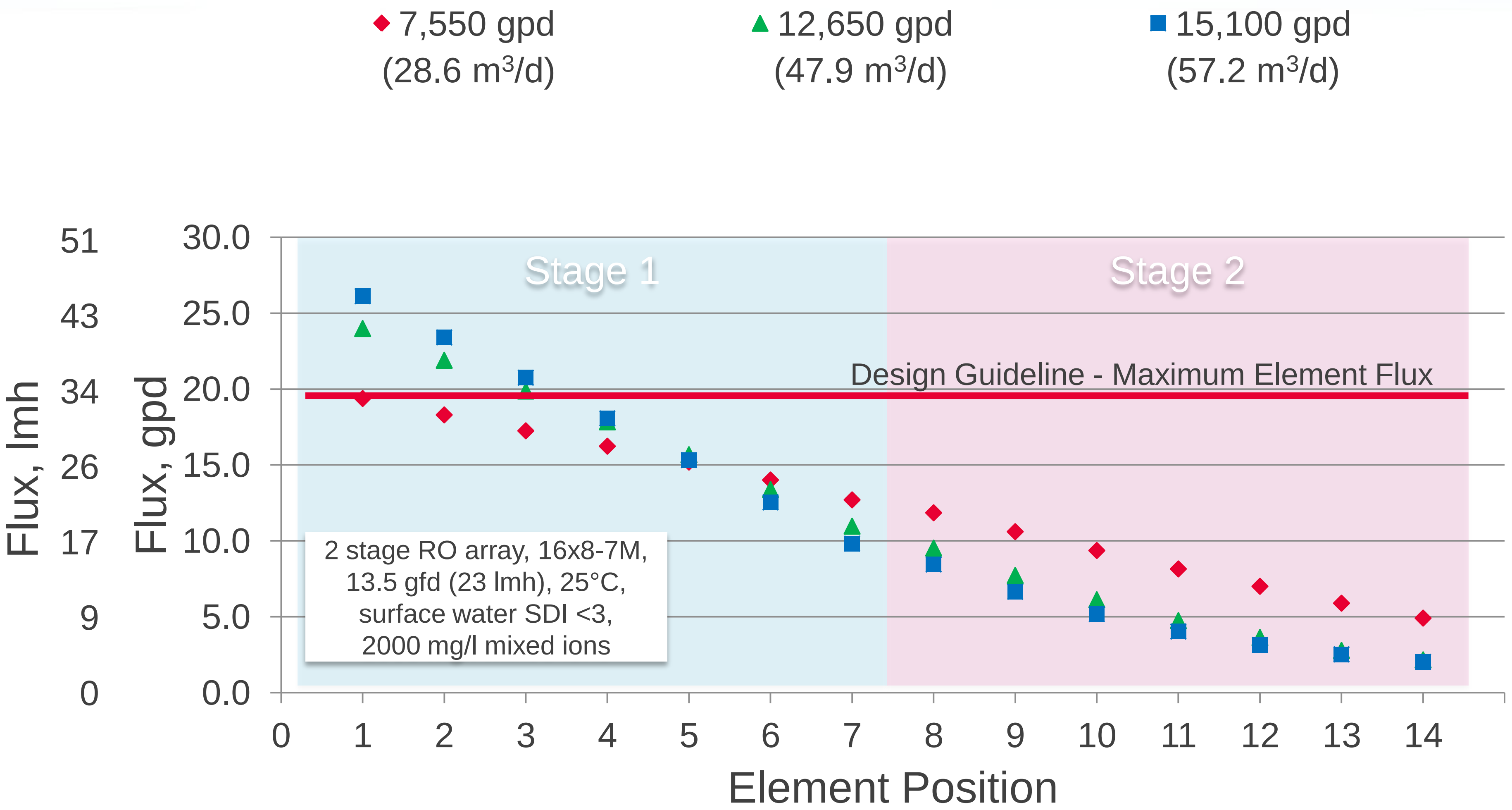
- Stage 1 permeate backpressure or stage 2 boost pump
- Multi-element hybrid array
- Internally Staged Design (ISD) array

Managing Permeate Quality

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

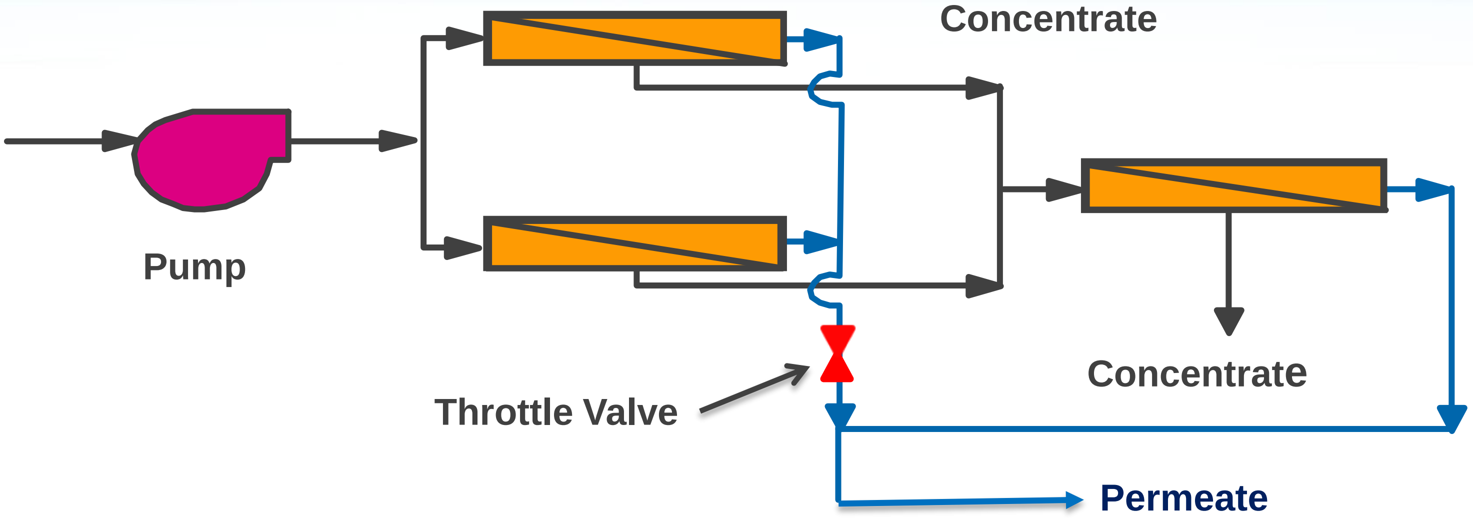
Stage-wise Flux Balancing

Element Flux Across 2 Stage Array



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

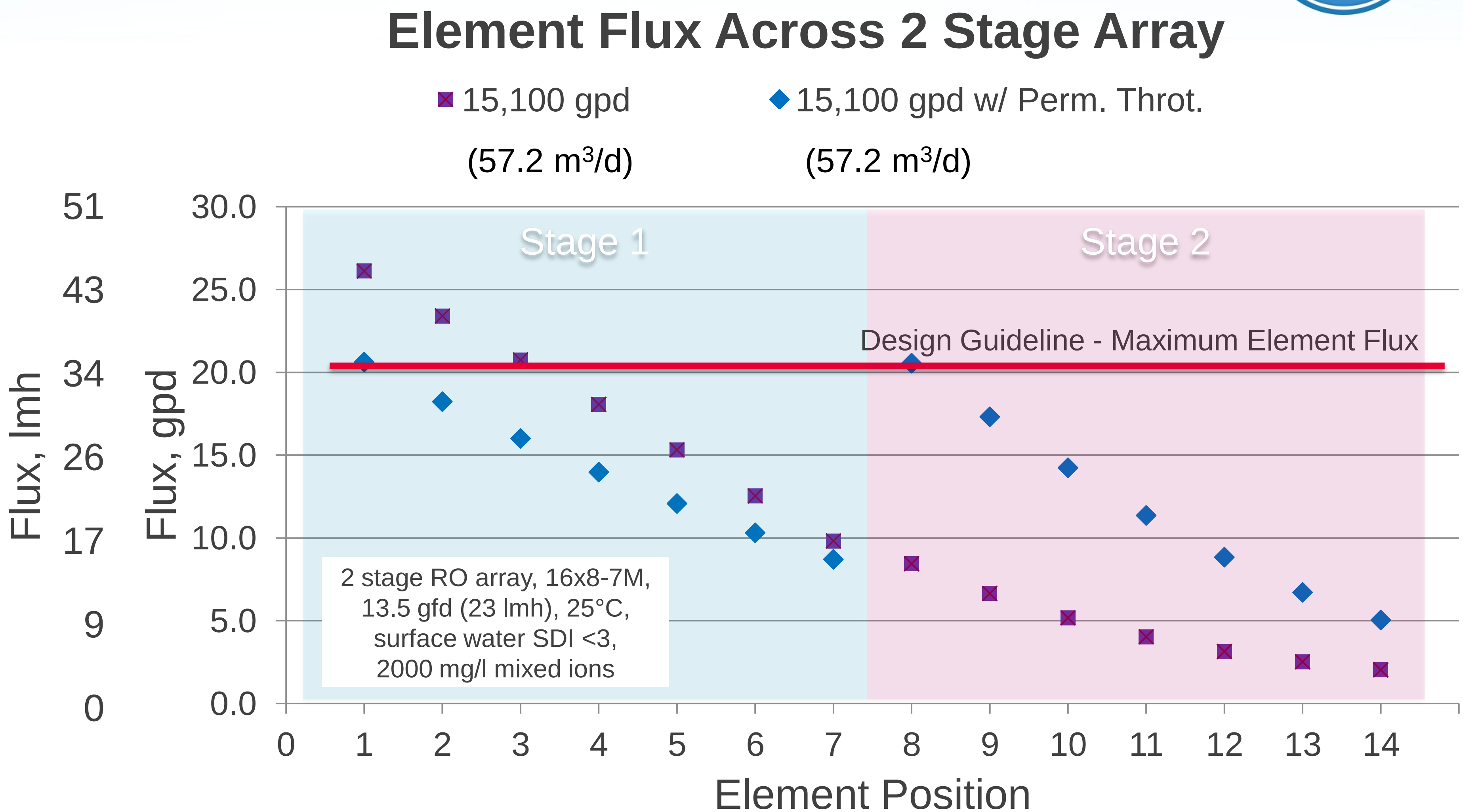


$$NDP = P_{feed} - \frac{DP}{2} - OP_{fb} - P_p + OP_p$$

Where:

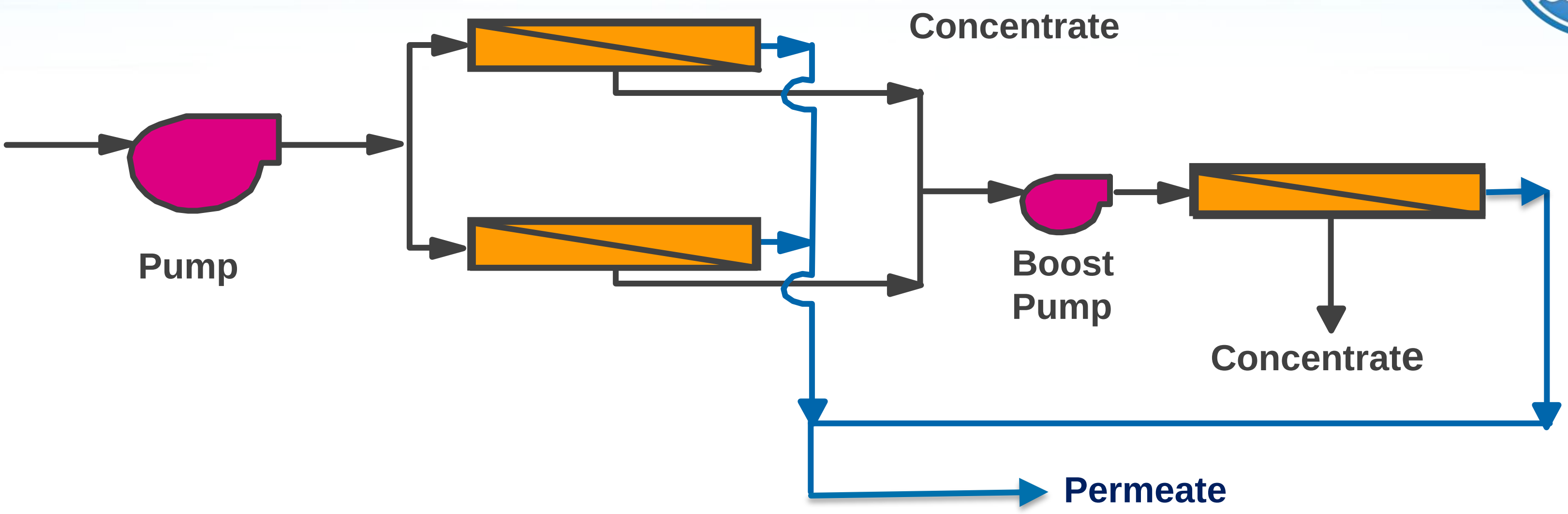
- NDP = Net Driving Pressure (psig)
- P_{feed} is feed pressure (psig)
- DP is differential pressure (psig)
- OP_{fb} is feed-brine osmotic pressure (psig)
- P_p is permeate pressure (psig)
- OP_p is permeate osmotic pressure (psig)

Balancing Flux with Stage 1 Permeate Pressure



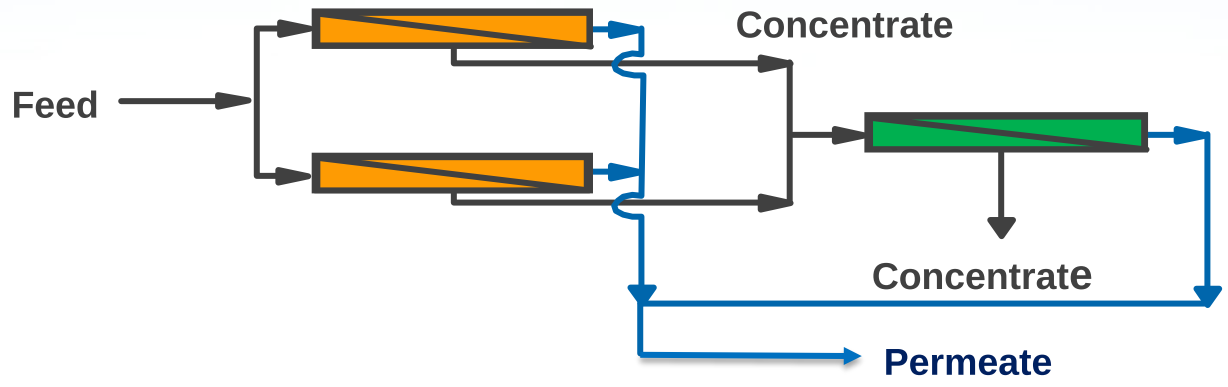
Element gpd tested at 150 psig (10.3 barg), 2000 mg/l NaCl, 25°C, pH 8, 15% recovery

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

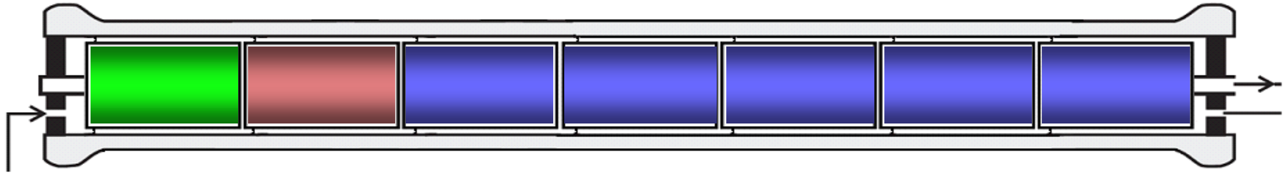
Multi-Element Hybrid Array



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

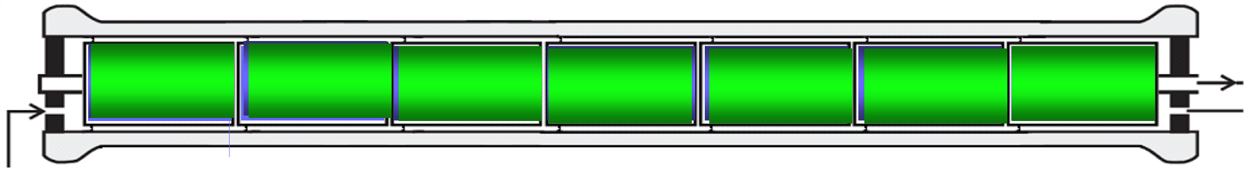
Internally Staged Design (ISD) RO Array

Internally Staged Design

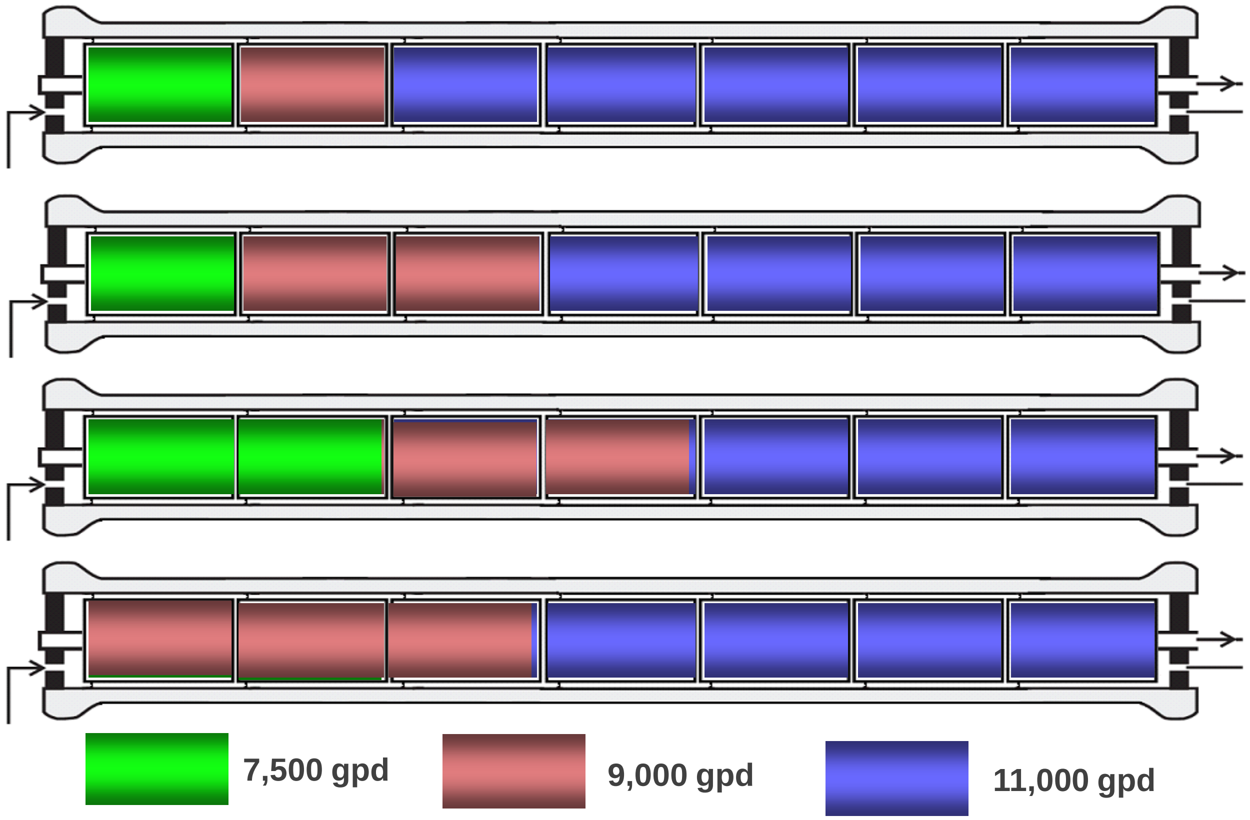


- Multiple RO element types used in a stage
- Common method to control element flux and to optimize energy consumption in seawater systems
- Common method to minimize post-treatment chemical addition in municipal drinking water RO/NF systems

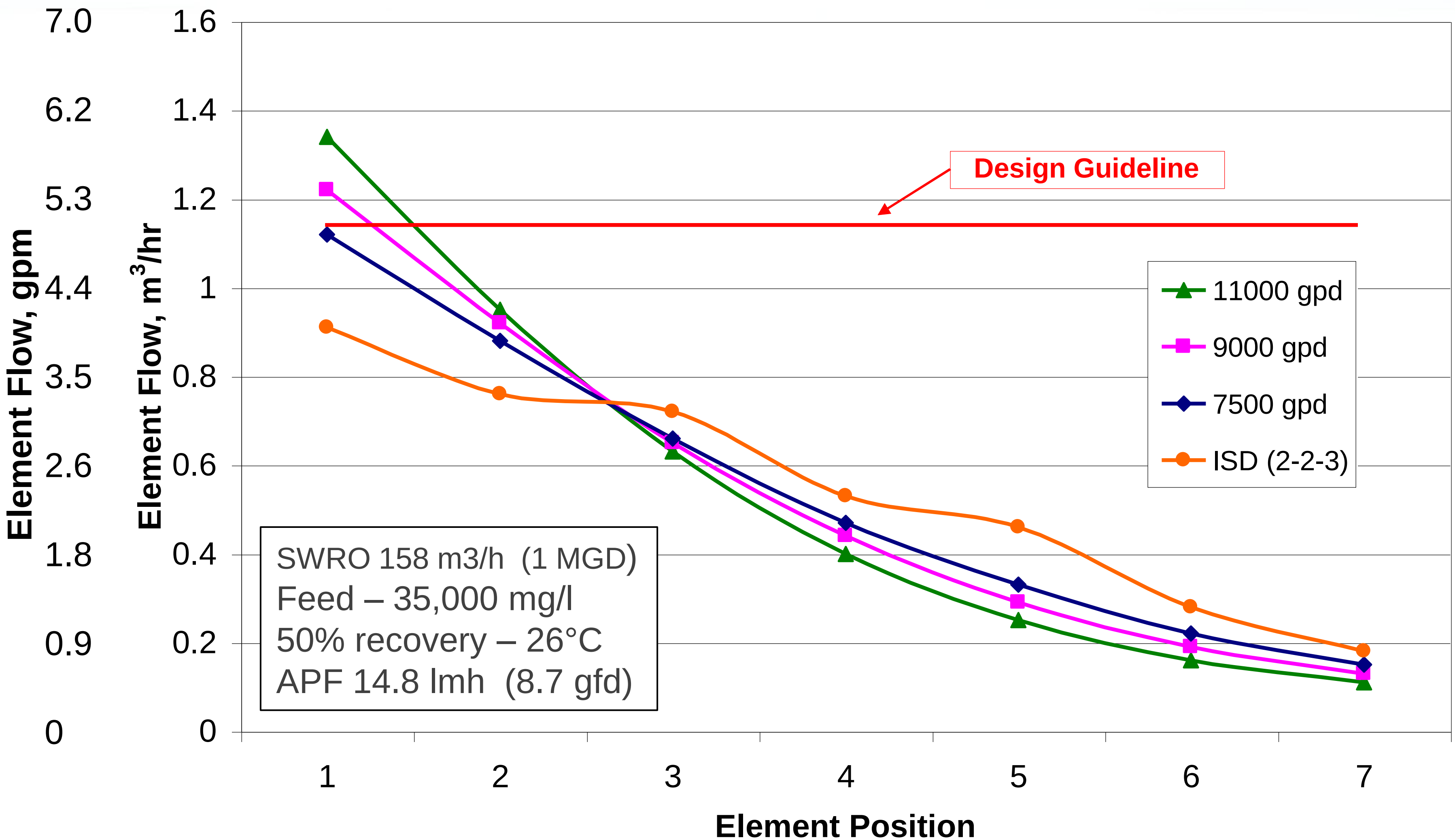
SWRO Element Loading Options



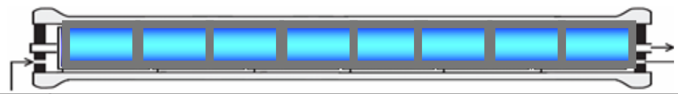
Examples of Potential FILMTEC™ ISD Element Loading Options

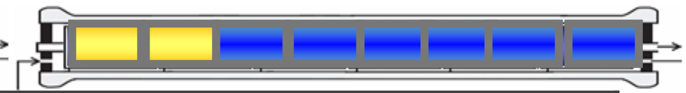


Using ISD to Optimize SWRO Performance



Configuration – Internally Staged Design



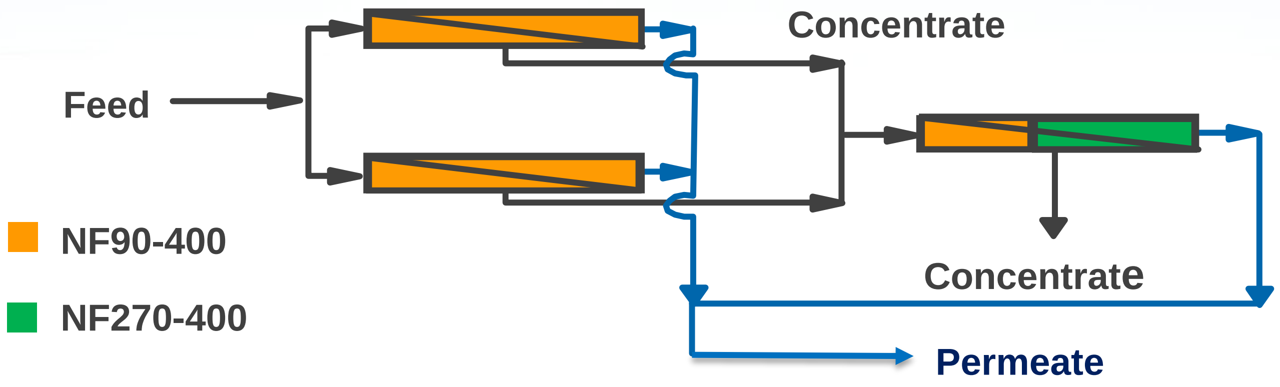


Average Flux of the vessel	14 lmh (8.2 gfd)	15.8 lmh (9.2 gfd)
Maximum permeate flow per element	0.99 m^3/h (4.4 gpm)	0.99 m^3/h (4.4 gpm)
COST of Water Highest FF & T	60.14 UScts/m^3 (228 UScts/kgal)	58.27 UScts/m^3 221 UScts/kgal)
COST of Water Lowest FF & T	63.65 UScts/m^3 (241 UScts/kgal)	60.05 UScts/m^3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

SW30HRLE-400i SW30XHR-400i SW30ULE-400i

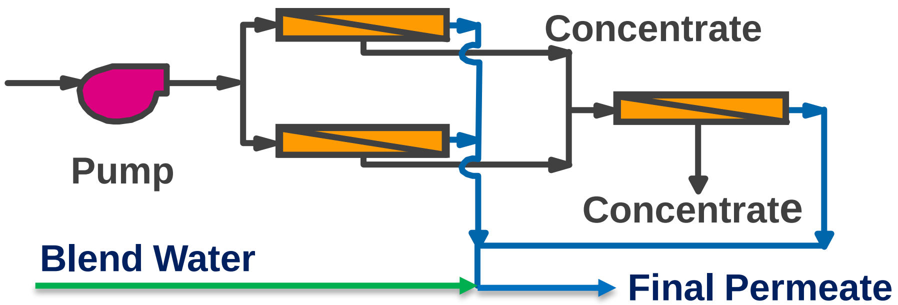
* COST CALCULATION (TOOLS): CAPEX and OPEX are taken into account. Model is prepared by a Consulting Company* for Dow *(John Tonner Water Consultants International Inc.)*

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

<u>Sources of Blend Water</u>

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

DBPFP = disinfection byproducts formation potential

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 $CaCO_3$	91 mg/l as $CaCO_3$
RO Specific Energy	1.22 kWh/kgal	1.11 kWh/kgal

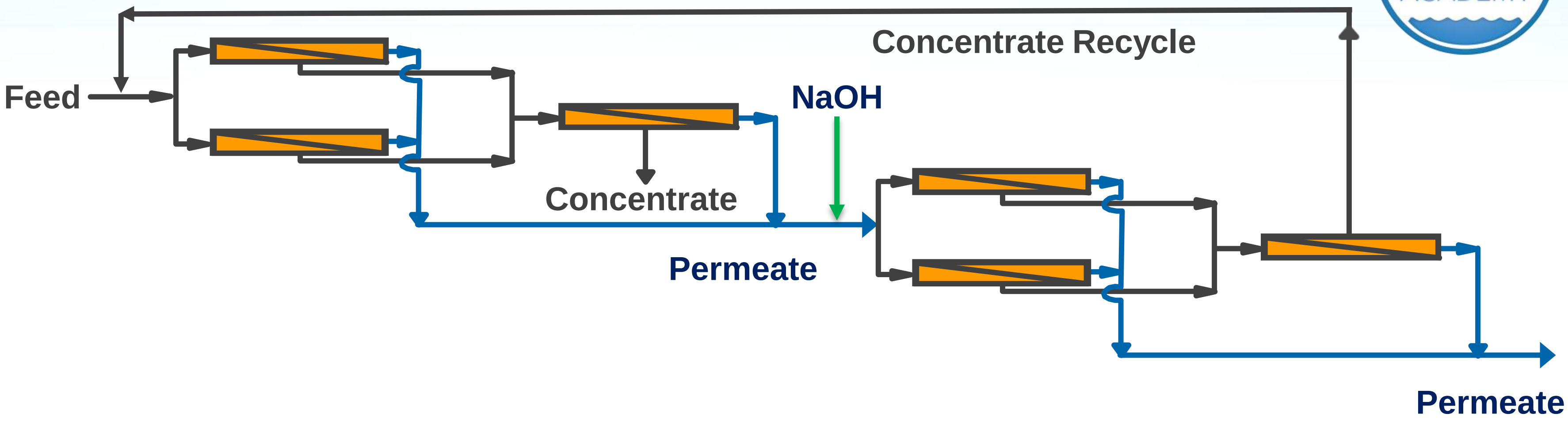
CAPEX Savings

- **12.5% fewer vessels**
- **12.5% fewer elements**

OPEX Savings

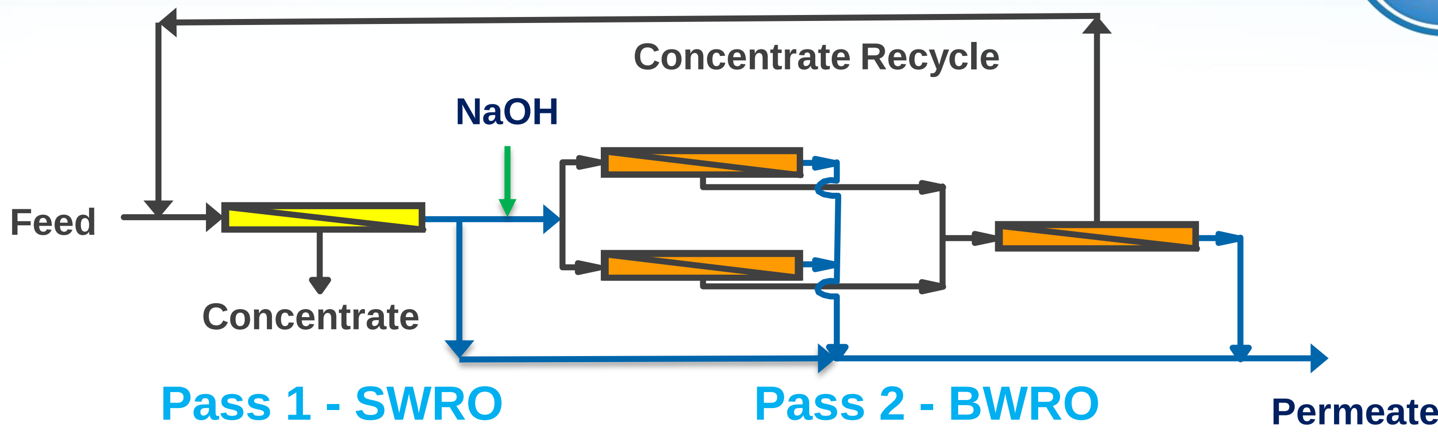
- **9% lower energy**
- **Reduced post-treatment**

2 Pass RO Design



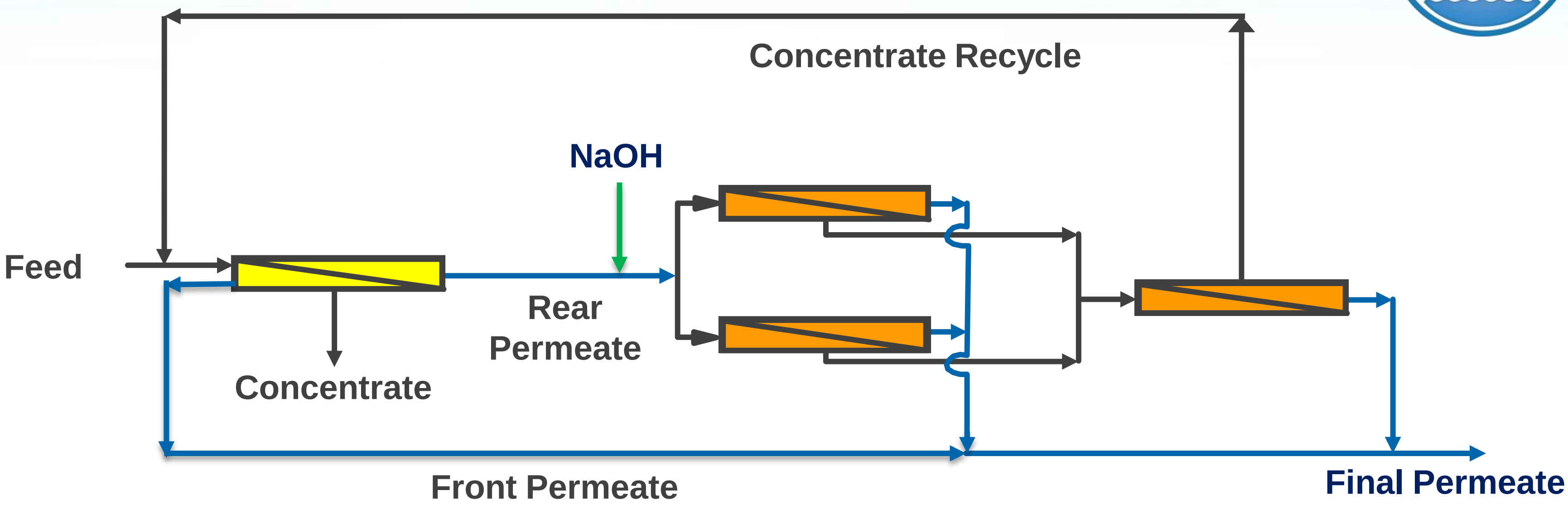
- 2 pass RO systems are primarily used when high purity permeate is required.
- Typical applications include boiler feed water, semiconductor rinse water, some seawater municipal plants, etc.
- Inter-pass pH adjustment with sodium hydroxide is commonly used to enhance rejection of alkalinity, boron,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

SWRO Design with Partial 2nd Pass



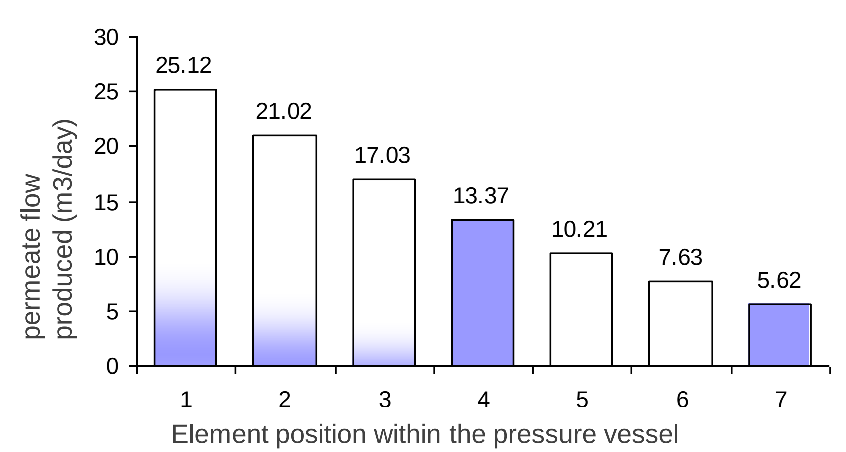
- SWRO design with a partial 2nd pass is primarily used to produce municipal drinking water
- This design saves both CAPEX and OPEX
- Percentage of 1st pass permeate treated with 2nd pass is a function of the feed water salinity and required final permeate salinity

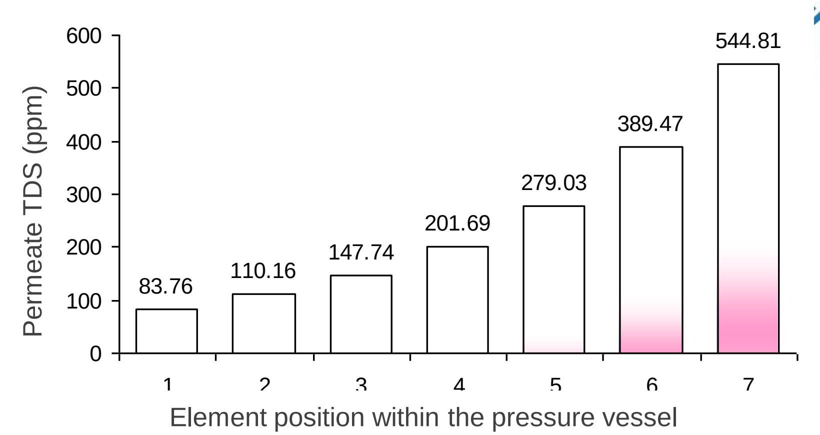
Split Permeate SWRO – Partial 2 Pass

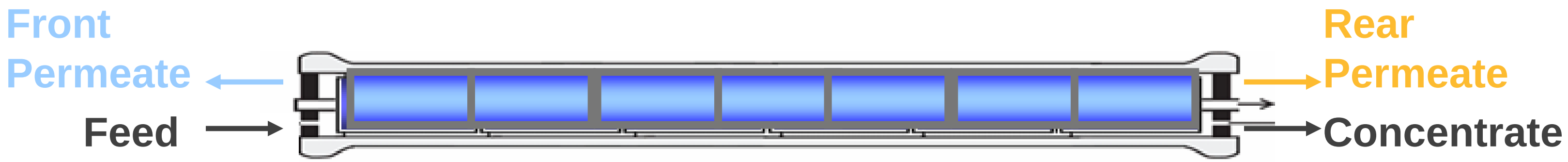


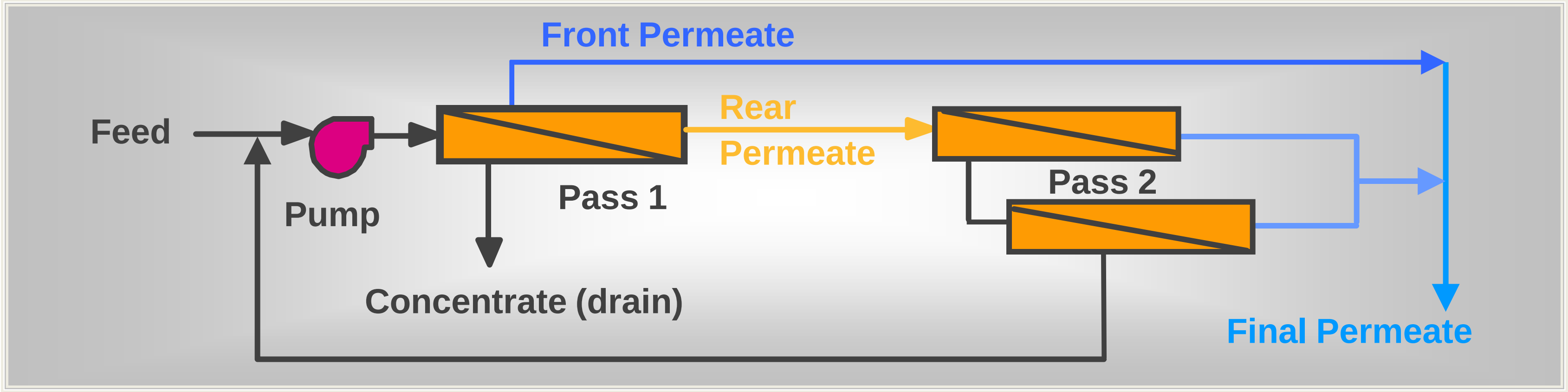
- Split permeate SWRO systems withdraw permeate from both ends of the first stage pressure vessels
- Front permeate is lower in salinity and is directly blended into the final permeate stream
- Ratio of front/rear permeate is typically controlled by pass 2 feed pump
- Many split permeate SWRO systems 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

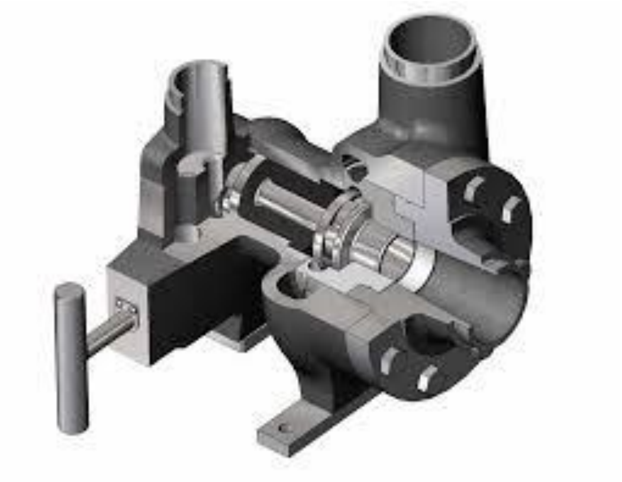
- Energy Recovery Devices (ERD) are used to capture and use residual concentrate stream pressure to:
  - Increase feed pressure prior to final high pressure pump (HPP)
  - Augment electrical drive motor on HPP
  - Provide inter-stage boost pressure on multi-stage RO and NF
- ERDs are used on virtually 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

WATER ACADEMY

- 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.

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

P = pressure

Q = flow rate

Eff = ERD efficiency

Subscripts:

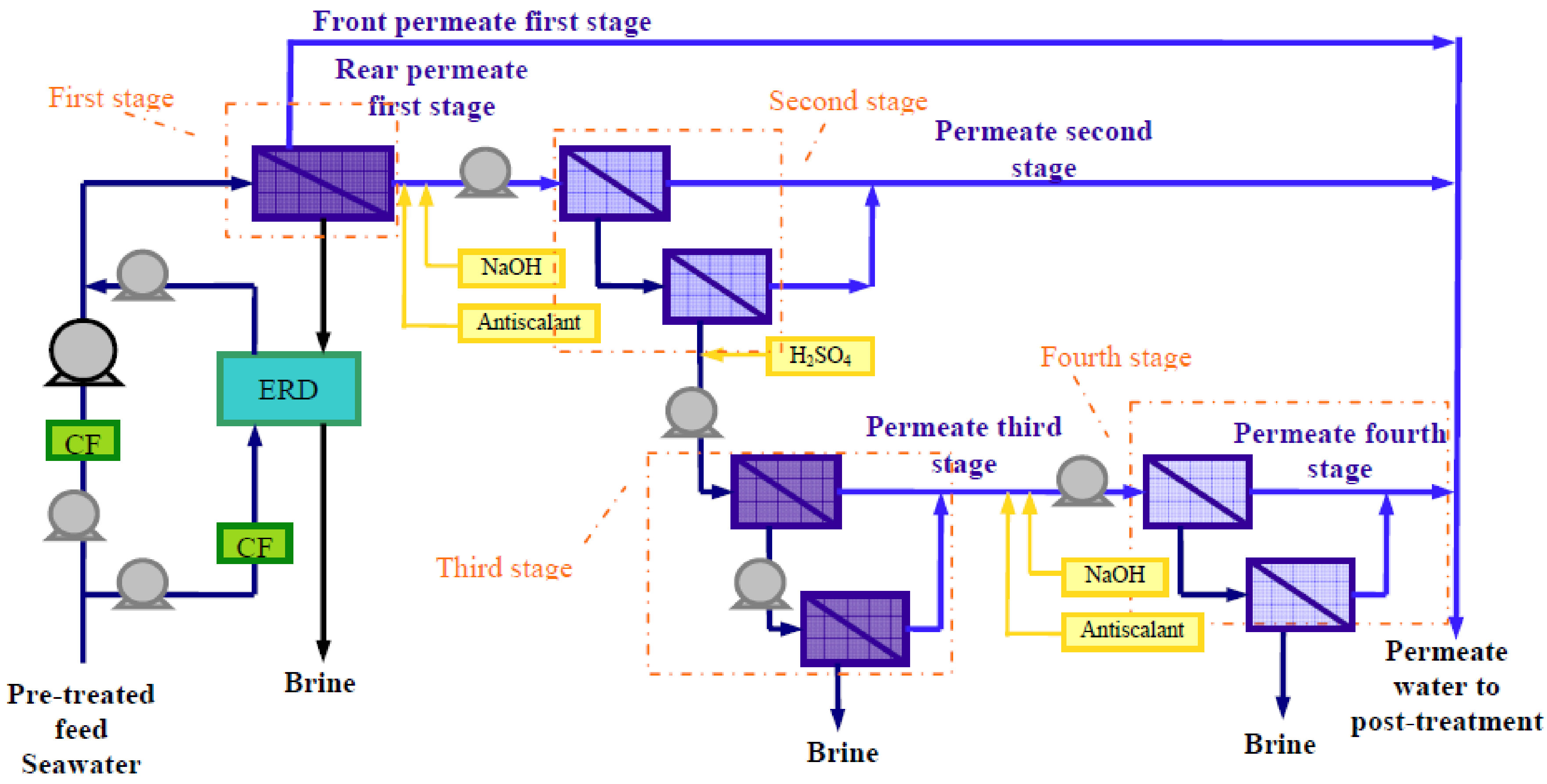
avail = available

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

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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

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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

Steven Coker
Technical Service Specialist

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

Sign up today!

Questions?

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

http://www.dowwaterandprocess.com/

WATER & PROCESS SOLUTIONS

WATER ACADEMY

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

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
1-3 pm CDT

Advanced RO System Design with ROSA

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

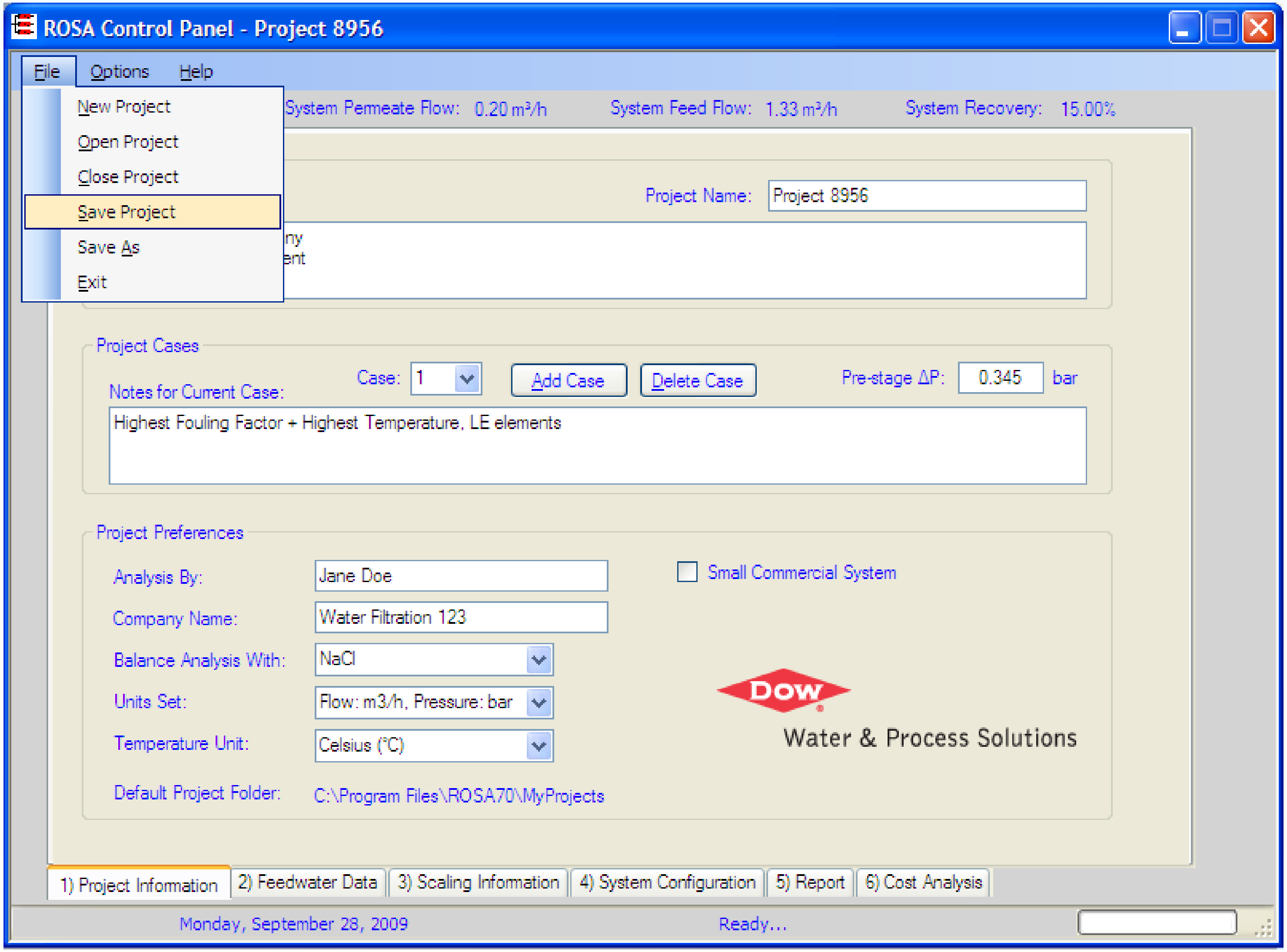
Reverse Osmosis System Analysis (ROSA)

- **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.

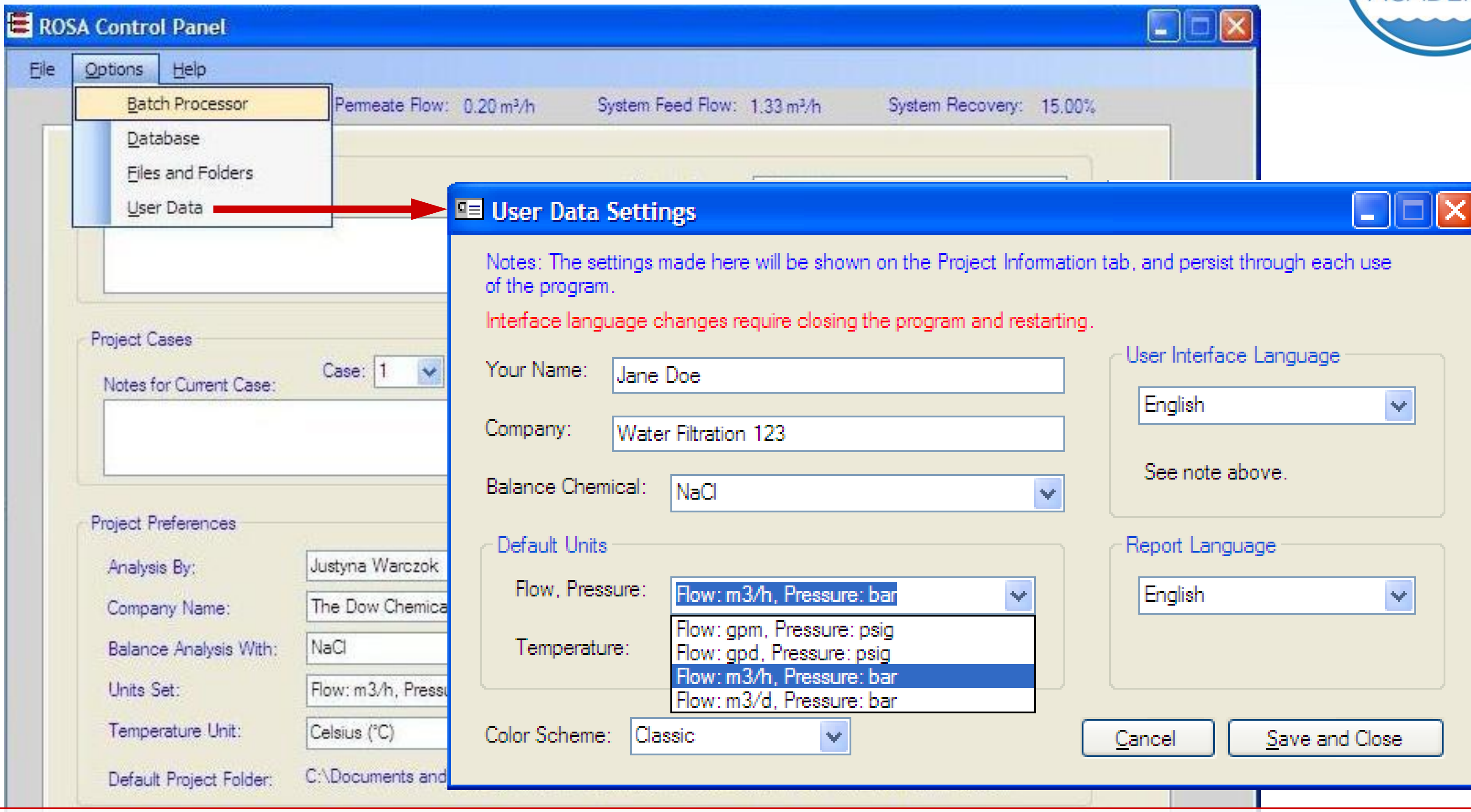
ROSA – Introduction to RO Plant Design

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

ROSA – Control Panel: File

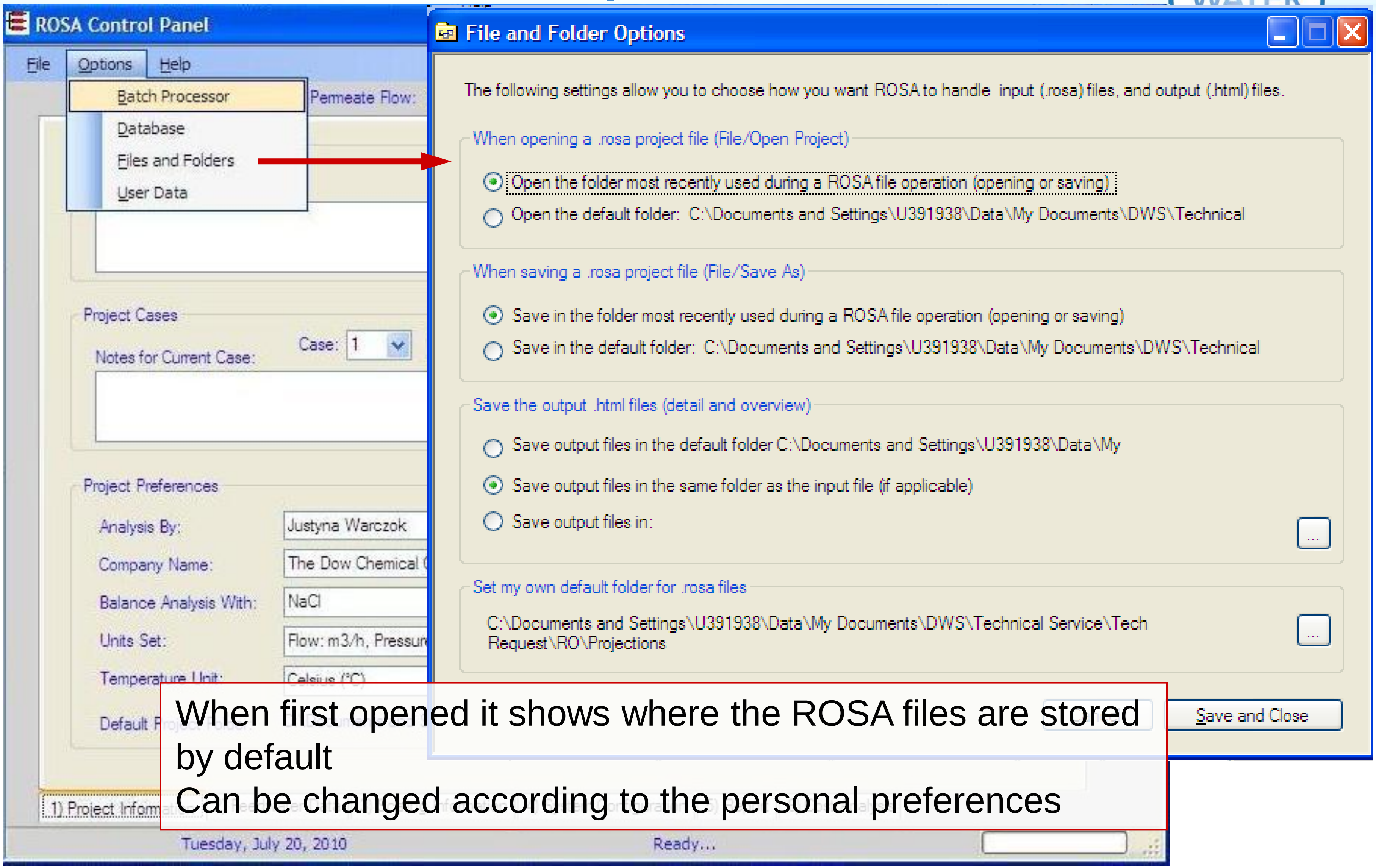


ROSA – Control Panel: Options



User Data Settings – stores introduced and selected information

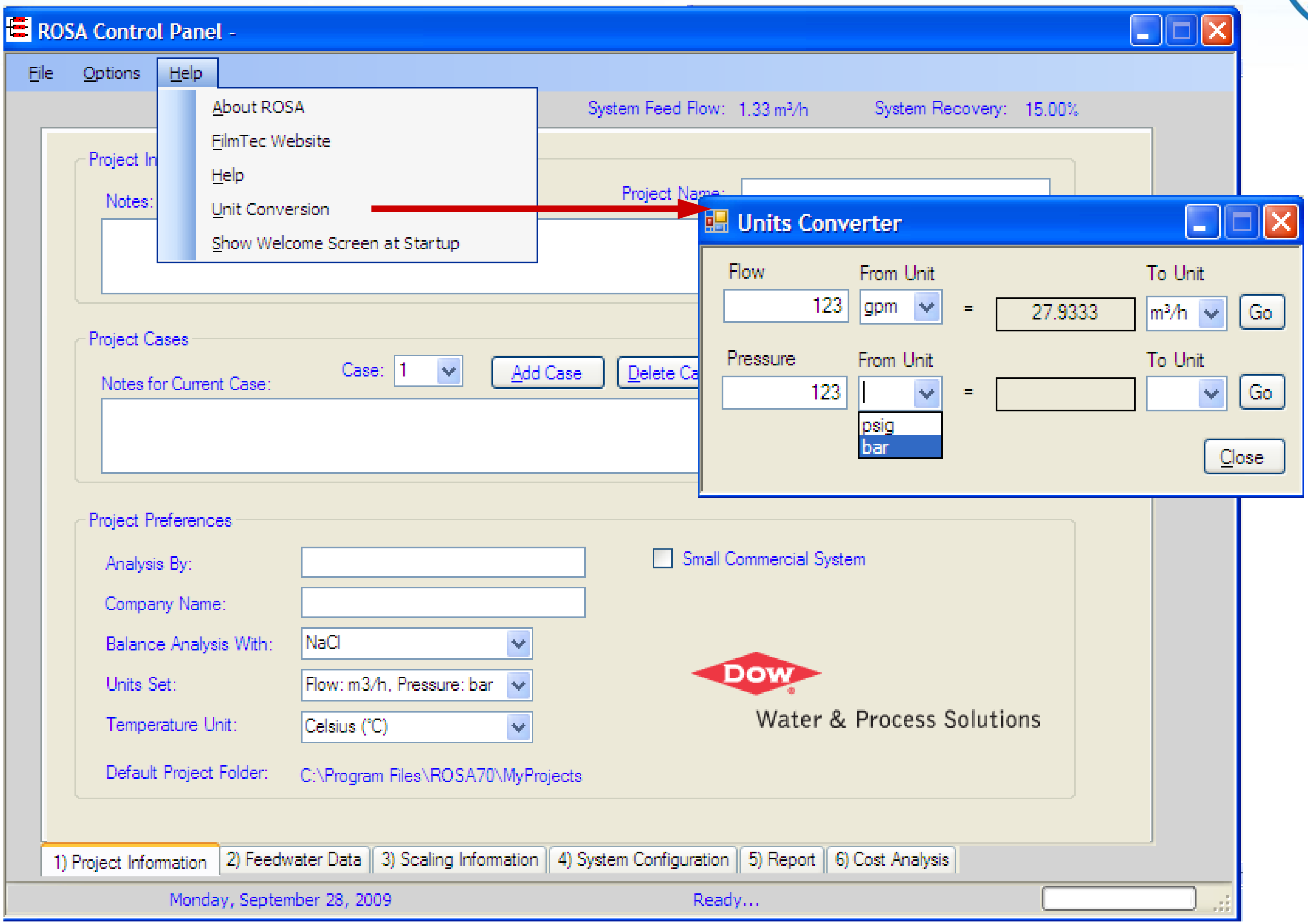
ROSA – Control Panel: Options



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

Can be changed according to the personal preferences

ROSA – Control Panel: Help

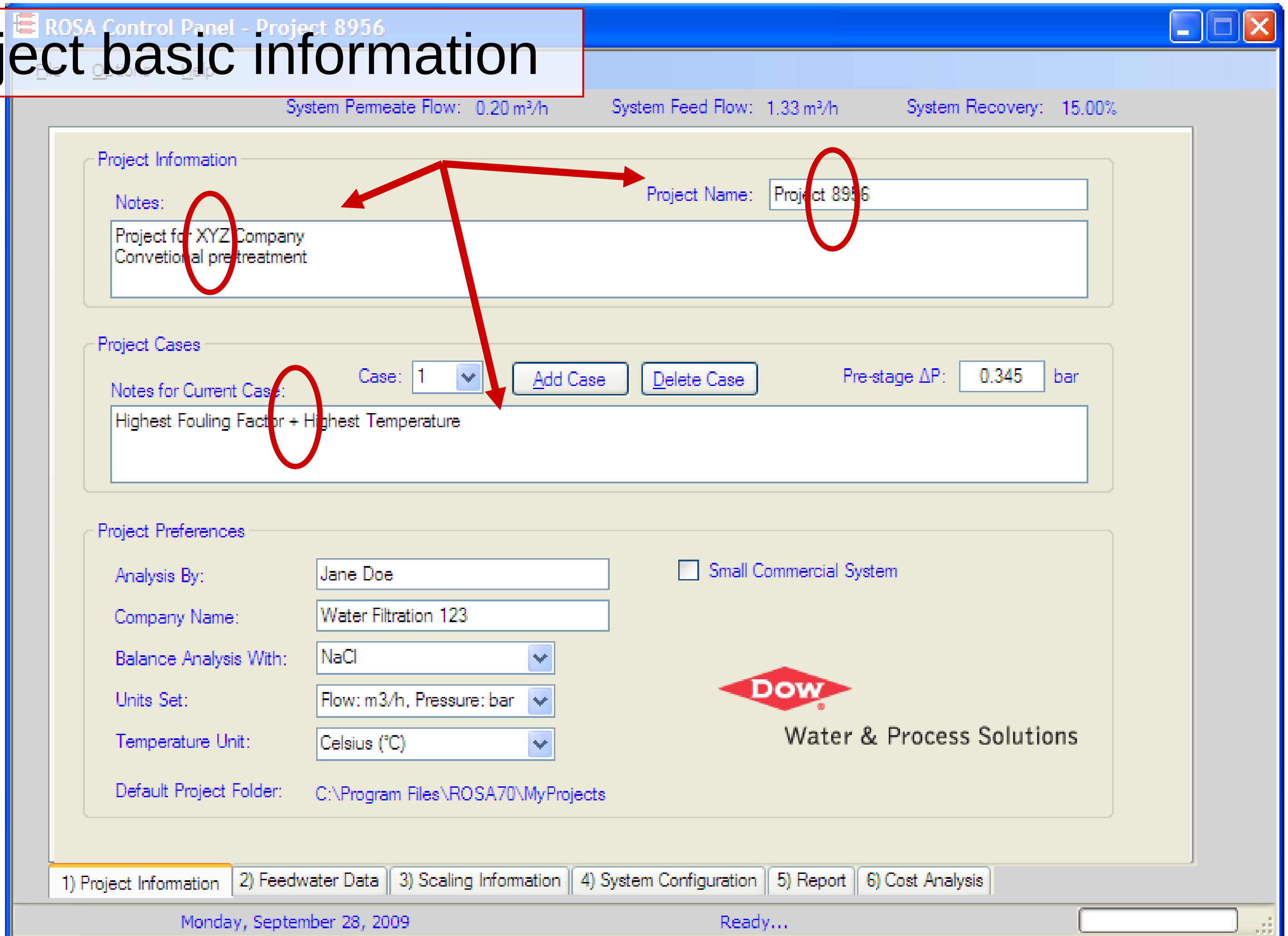


Plant Design using ROSA

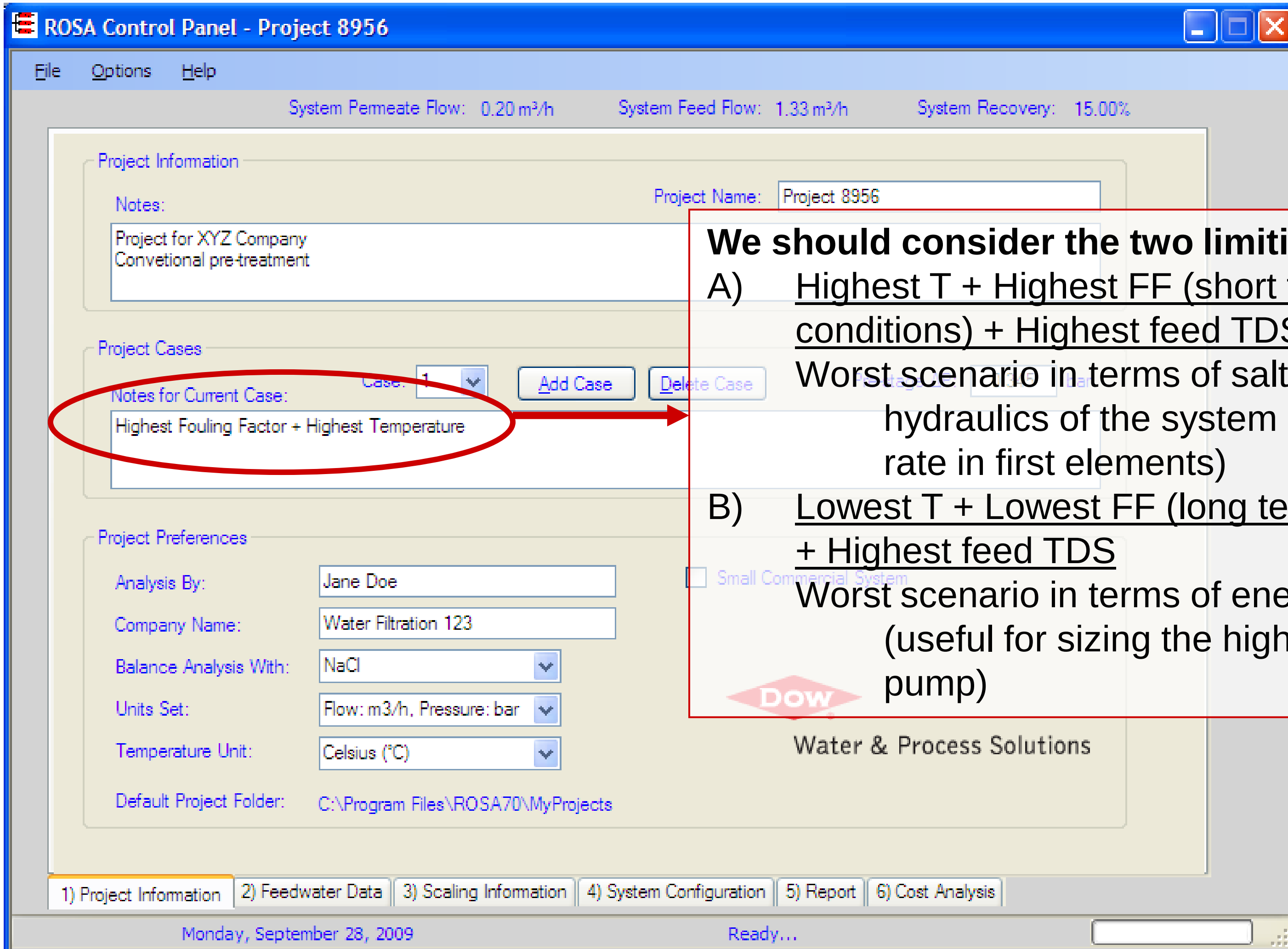
- Project Information
- Feedwater Data
- Scaling Information
- System Configuration
- Report

ROSA – Project Description

Project basic information



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:

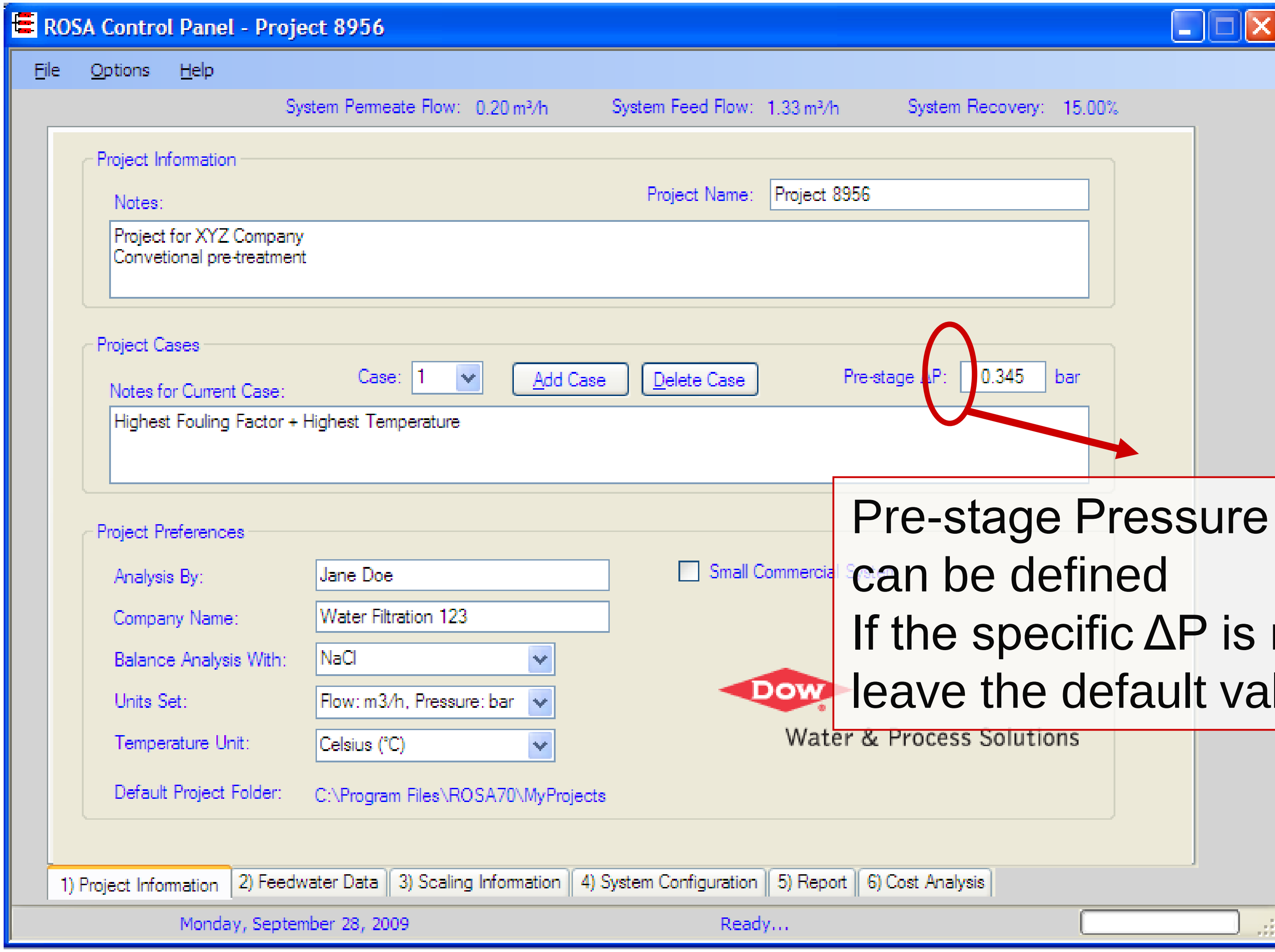
- FF = 1.00 Nominal element flow performance according to specification
- FF = 0.80 80% of nominal element flow performance

	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



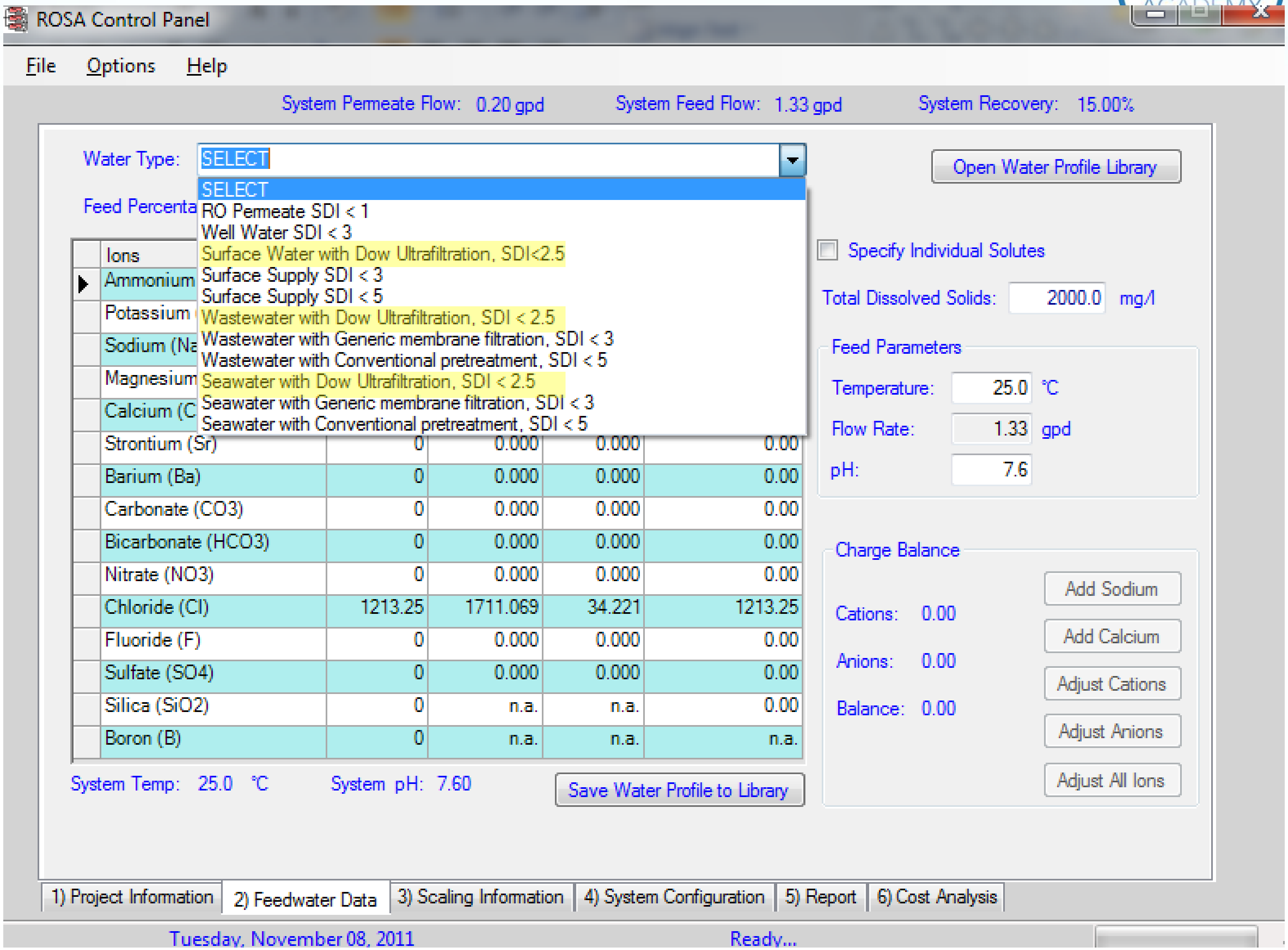
Pre-stage Pressure Drop (ΔP) can be defined

If the specific ΔP is not known, leave the default value

Plant Design using ROSA

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

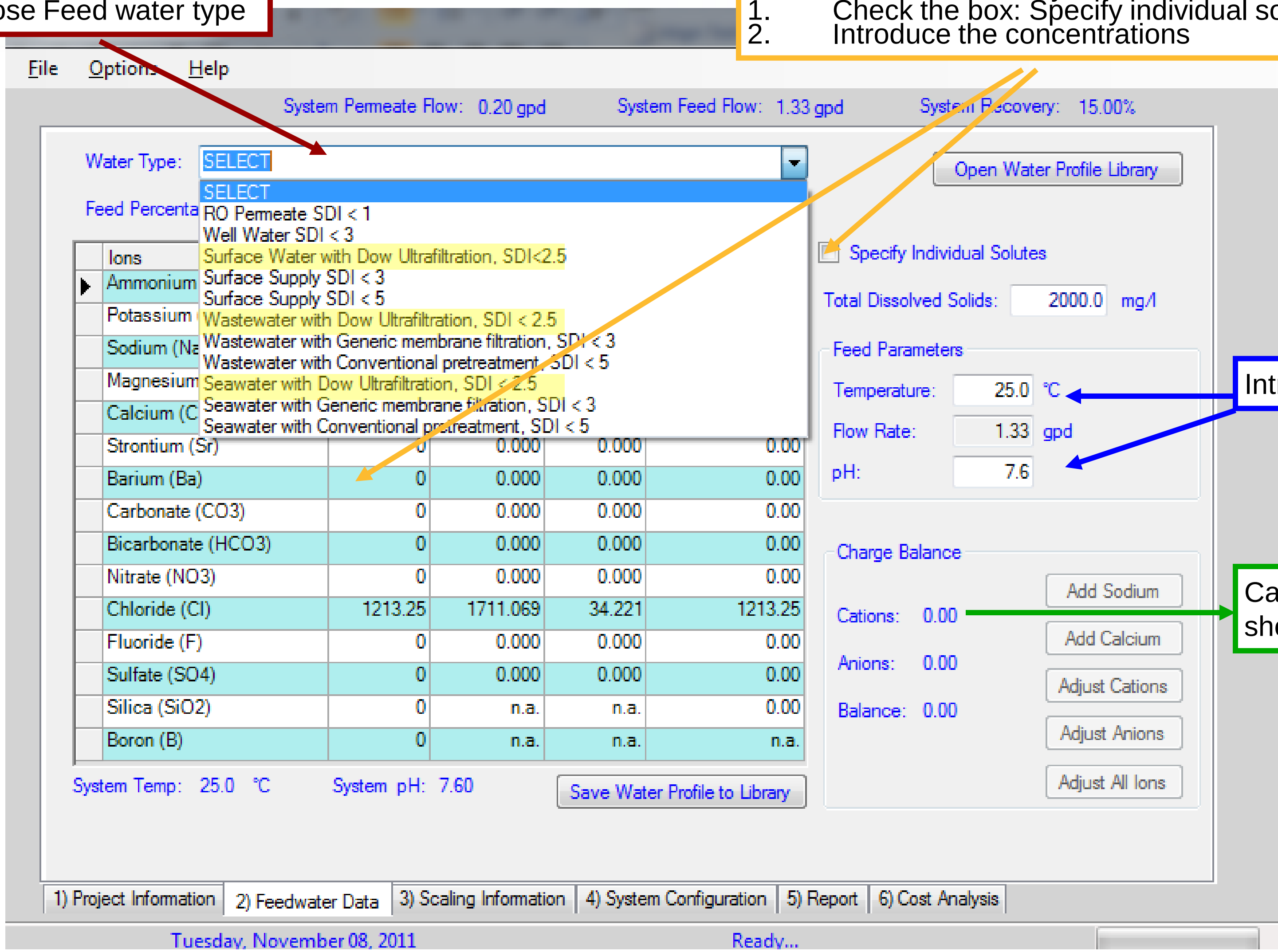
Addition of DOW™ Ultrafiltration Water Types



ROSA – Introducing Feed water analysis

Choose Feed water type

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



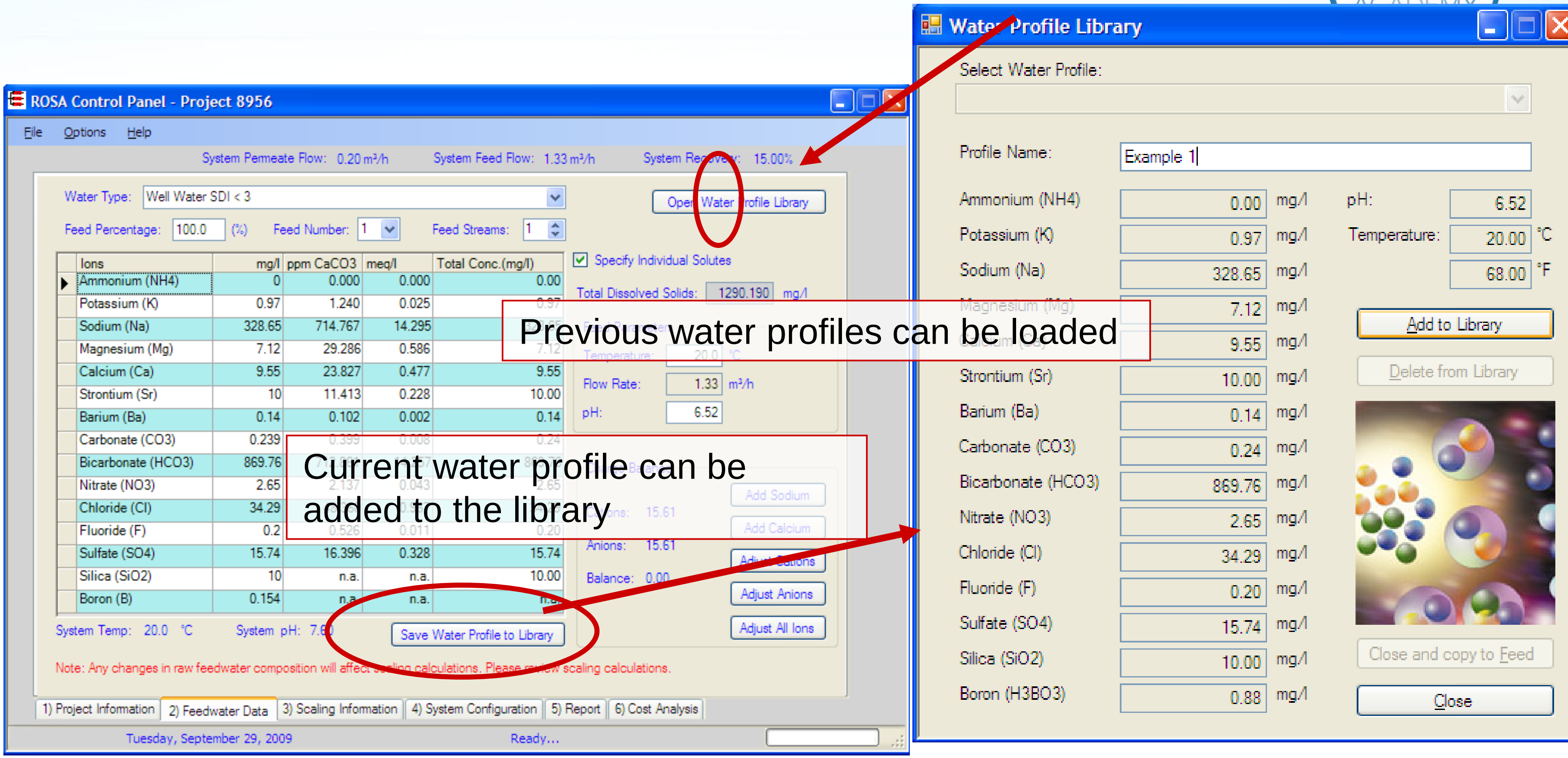
Introduce the T and pH

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

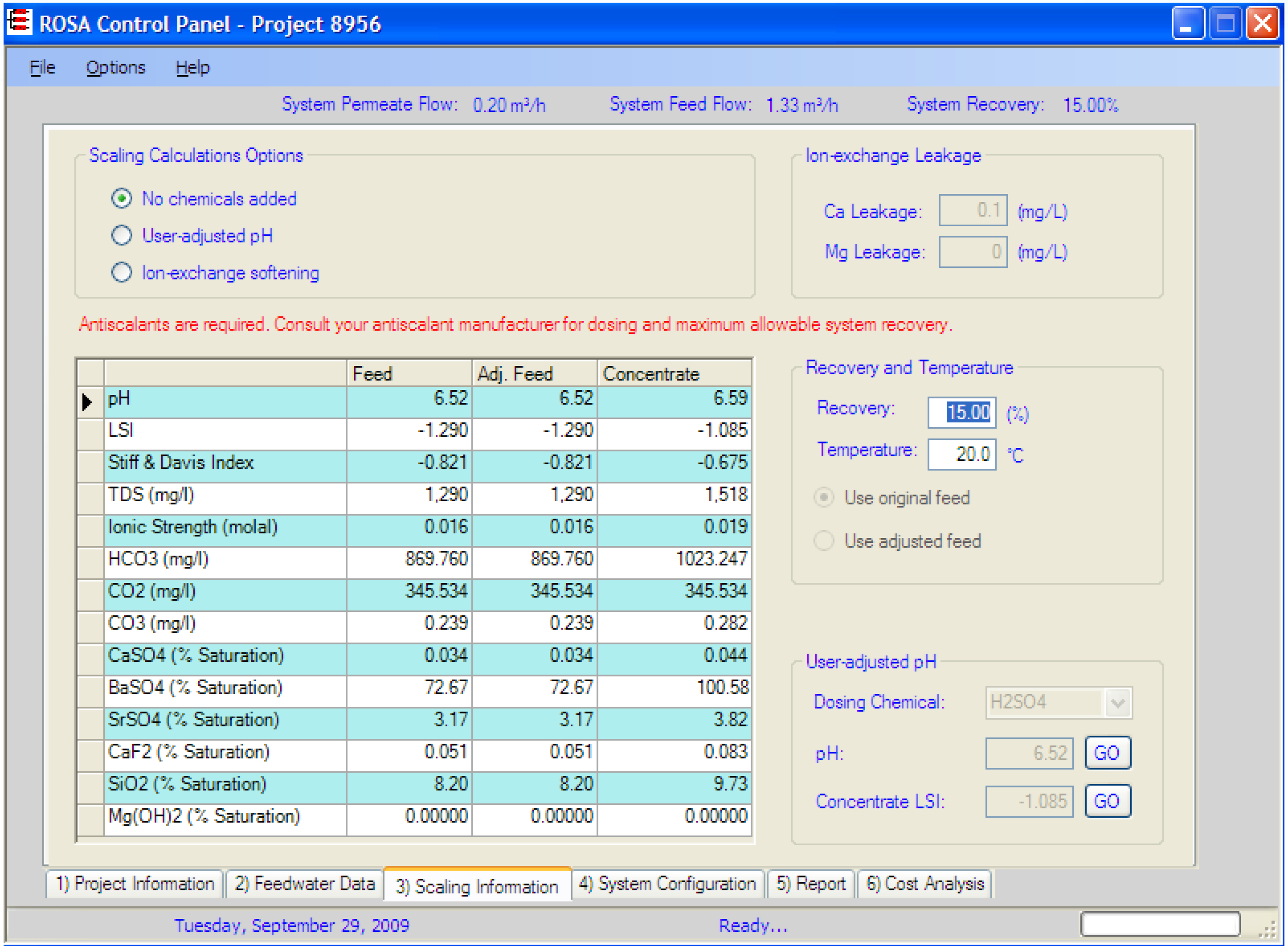
ROSA – Saving the Water Profile



Plant Design using ROSA

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

ROSA – Scaling Information



	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
HCO3 (mg/l)	869.760	869.760	1023.247
CO2 (mg/l)	345.534	345.534	345.534
CO3 (mg/l)	0.239	0.239	0.282
CaSO4 (% Saturation)	0.034	0.034	0.044
BaSO4 (% Saturation)	72.67	72.67	100.58
SrSO4 (% Saturation)	3.17	3.17	3.82
CaF2 (% Saturation)	0.051	0.051	0.083
SiO2 (% Saturation)	8.20	8.20	9.73
Mg(OH)2 (% Saturation)	0.00000	0.00000	0.00000

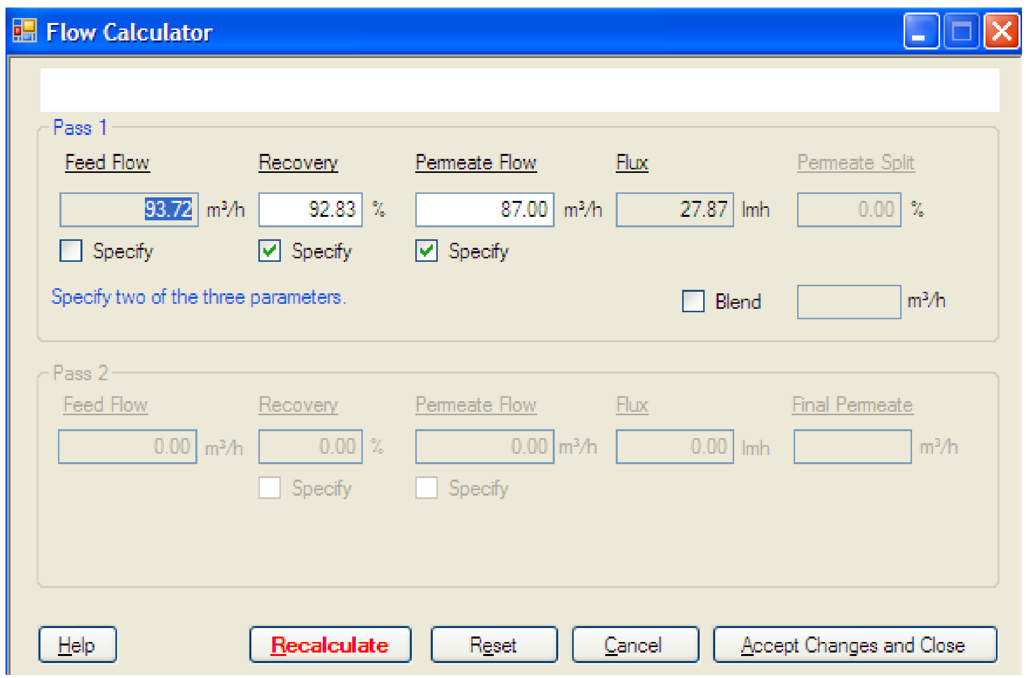
Plant Design using ROSA

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

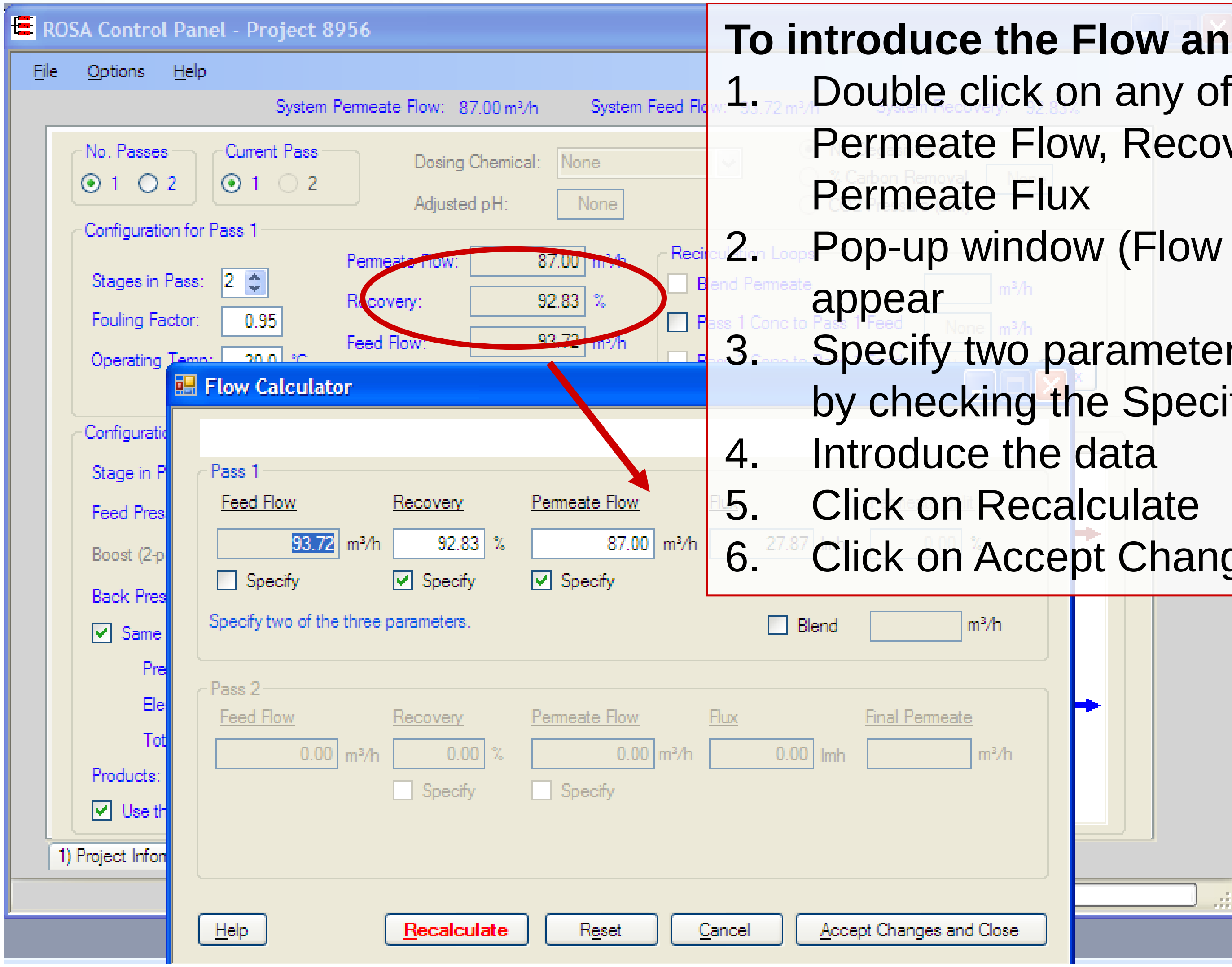
ROSA - Introduction of known data

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



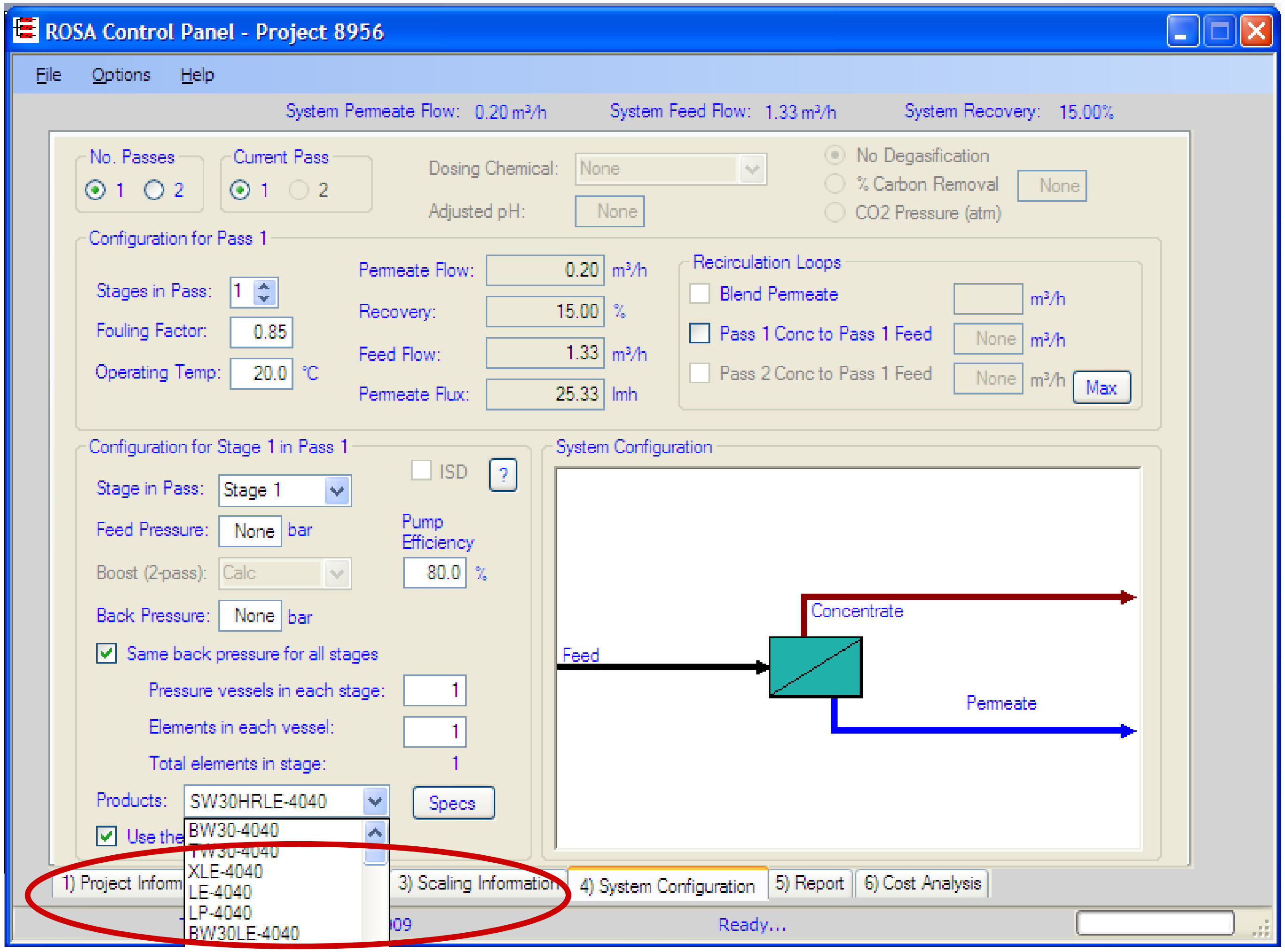
ROSA - Introduction of known data



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



WATER & PROCESS SOLUTIONS

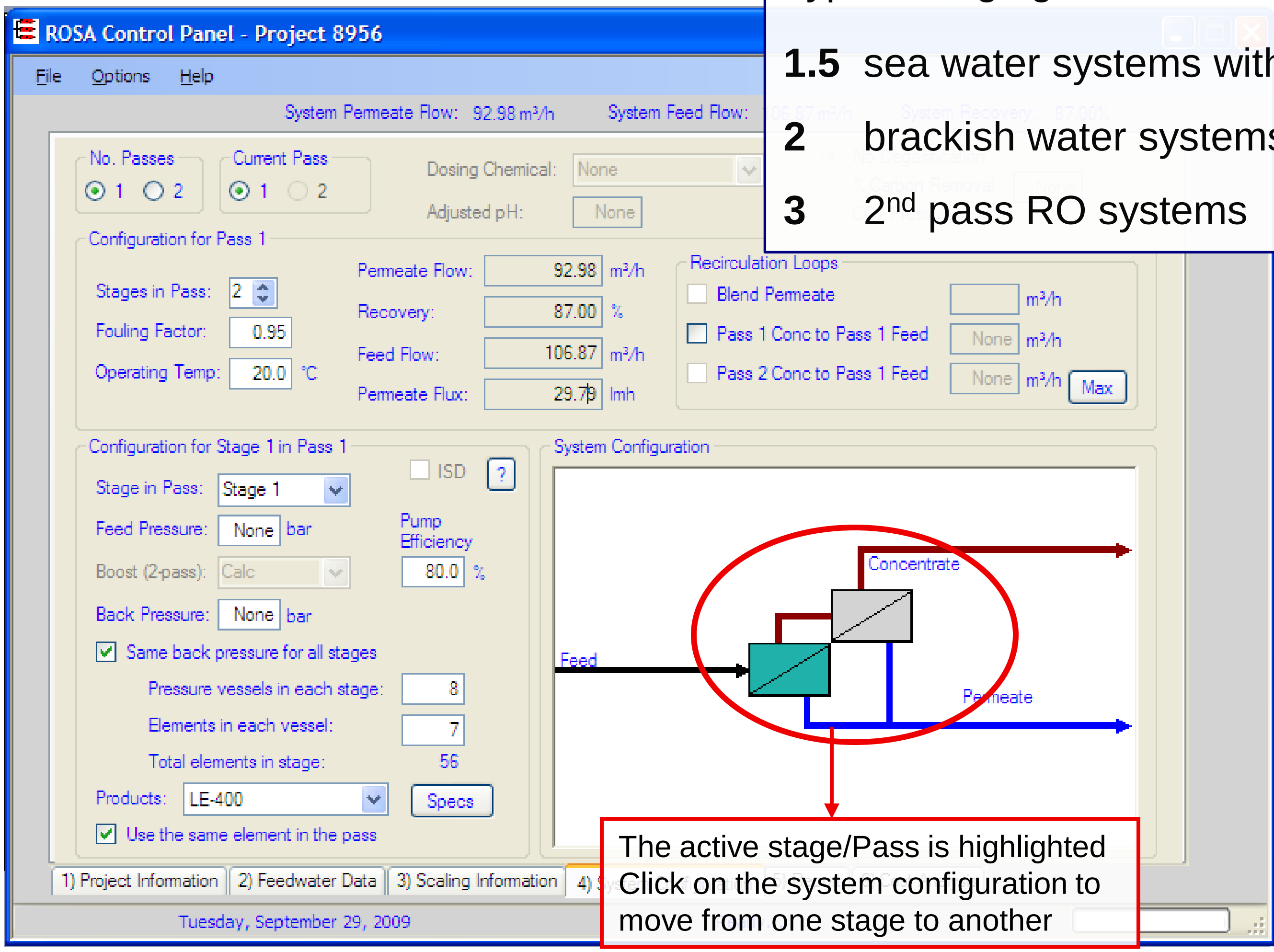
Multistage systems: Staging ratio calculation

Typical staging ratio:

1.5 sea water systems with 6-element vessels

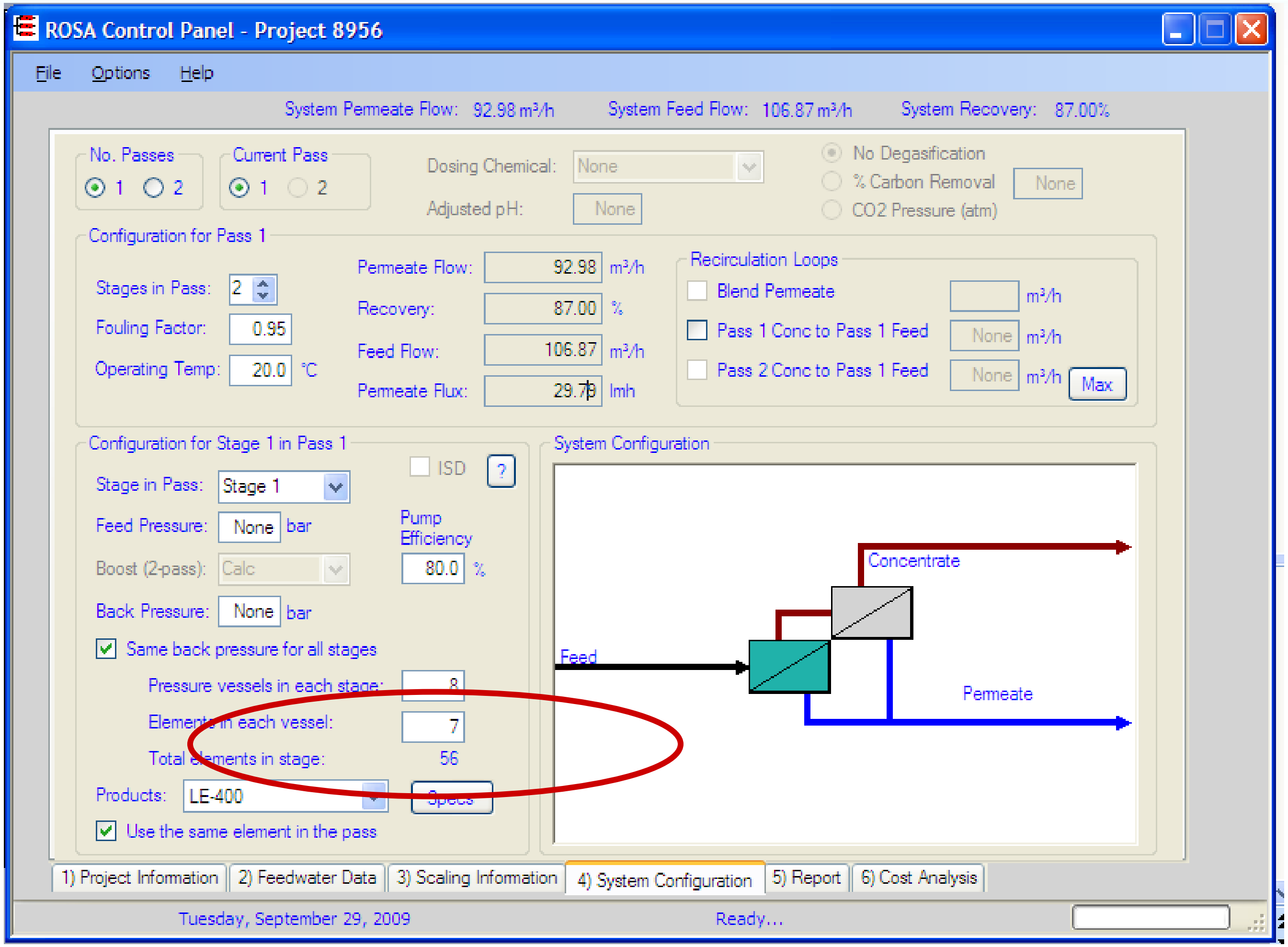
2 brackish water systems with 6-element vessels

3 2nd pass RO systems

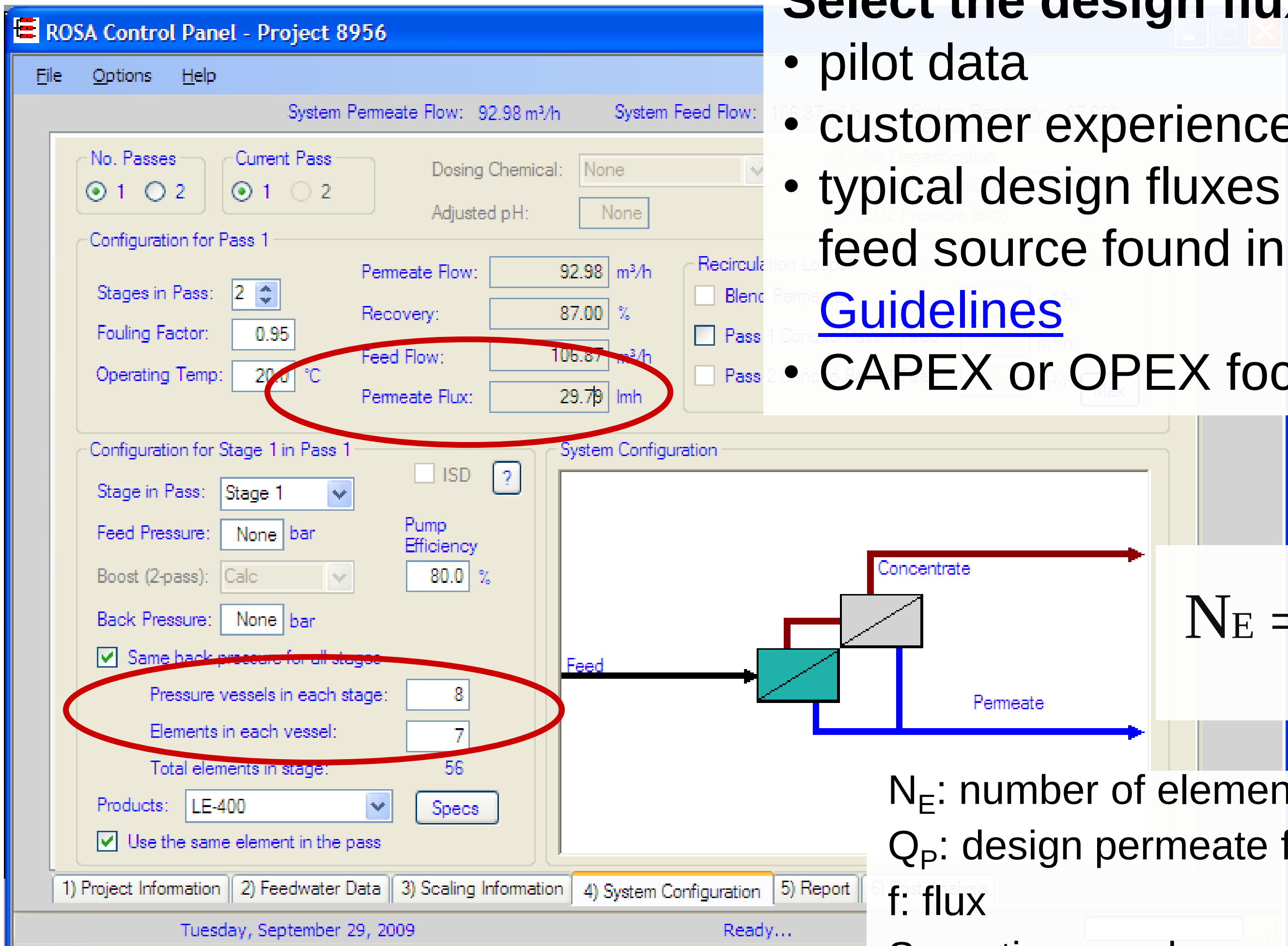


The active stage/Pass is highlighted
Click on the system configuration to move from one stage to another

Number of Elements per Pressure Vessel Selection



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 m³/h	Pass 1 Permeate Flow	92.97 m³/h	Osmotic Pressure:		
Raw Water Flow to System	106.87 m³/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 M²	Average Pass 1 Flux	29.78 lmh	Power		42.20 kW
Water Classification: Well Water SDI < 3				Specific Energy		0.45 kWh/m³

Stage	Element	#PV	#Ele	Feed Flow (m³/h)	Feed Press (bar)	Recirc Flow (m³/h)	Conc Flow (m³/h)	Conc Press (bar)	Perm Flow (m³/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	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: 1.44m³/h)
WARNING: Maximum element recovery has been exceeded. Please change your system design to reduce the element recoveries. (Product: LE-400, Limit: 19.00%)

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

Solubility Warnings

Langelier Saturation Index > 0
Stiff & Davis Stability Index > 0
BaSO4 (% Saturation) > 100%
Antiscalants may be required. Consult your antiscalant manufacturer for dosing and maximum allowable system recovery.

Stage Details

Stage 1	Element	Recovery	Perm Flow (m³/h)	Perm TDS (mg/l)	Feed Flow (m³/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	1.18	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 (m³/h)**	**Perm TDS (mg/l)**	**Feed Flow (m³/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

WATER ACADEMY

Design warning	Solutions
Max. element **permeate flow** exceeded	3, 5, 7, 11
The **concentrate flow** less than minimum	1, 5, 4 together with 6
The **feed flow** greater than maximum	2 unless the feed flow is fixed, 3
Maximum **feed pressure** exceeded	1, 3, 8
Temperature is above acceptable value	10
Max. element **recovery** exceeded: • If the problem is encountered in front elements • If the problem is encountered in rear elements	 1, 5, 6, 11 1, 5, 6

Solutions Guide

1 Decrease system recovery

2 Increase system recovery

3 Reduce average system flux (add membranes, PV)

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.)

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

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

8 Install lower energy membranes or ISD with lower energy membranes

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

11 Combine two element types: lower energy elements in rear positions (ISD configuration)

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

Warnings and typical solutions – For multistage systems

Design warning	Solutions
Max. element **permeate flow** exceeded	3, (5), 6, 10, 13
The **concentrate flow** less than minimum	1, 4, (5), 6, 7, (10 and 11 only for the 1st stage)
The **feed flow** greater than maximum in any of the stages	2, 3
Maximum **feed pressure** exceeded	1, 3, 9
Temperature is above acceptable value	12
Max. element **recovery** exceeded: • If the problem is encountered in front elements (front stage/s) • If the problem is encountered in rear elements (rear stage/s)	 1, (5), 6, 7, 10, 13 1, (5), 7

Solutions Guide

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.)

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

*APF – Average Permeate Flux
PV=Pressure Vessel

Further Help –Answer Center

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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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Reverse Osmosis System Design Basics

Date & Time
Sept 9, 2015
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ROSA System Design Basics

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Sept 11, 2015
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RO Webinar Series Speakers:

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Technical Service Specialists

Advanced Reverse Osmosis System Design

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Advanced RO System Design with ROSA

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Sept 30, 2015
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WATER & PROCESS SOLUTIONS

Reverse Osmosis System Analysis (ROSA) Advanced Design

Steven Coker
Dow Water & Process Solutions

RO System Design Webinar Series

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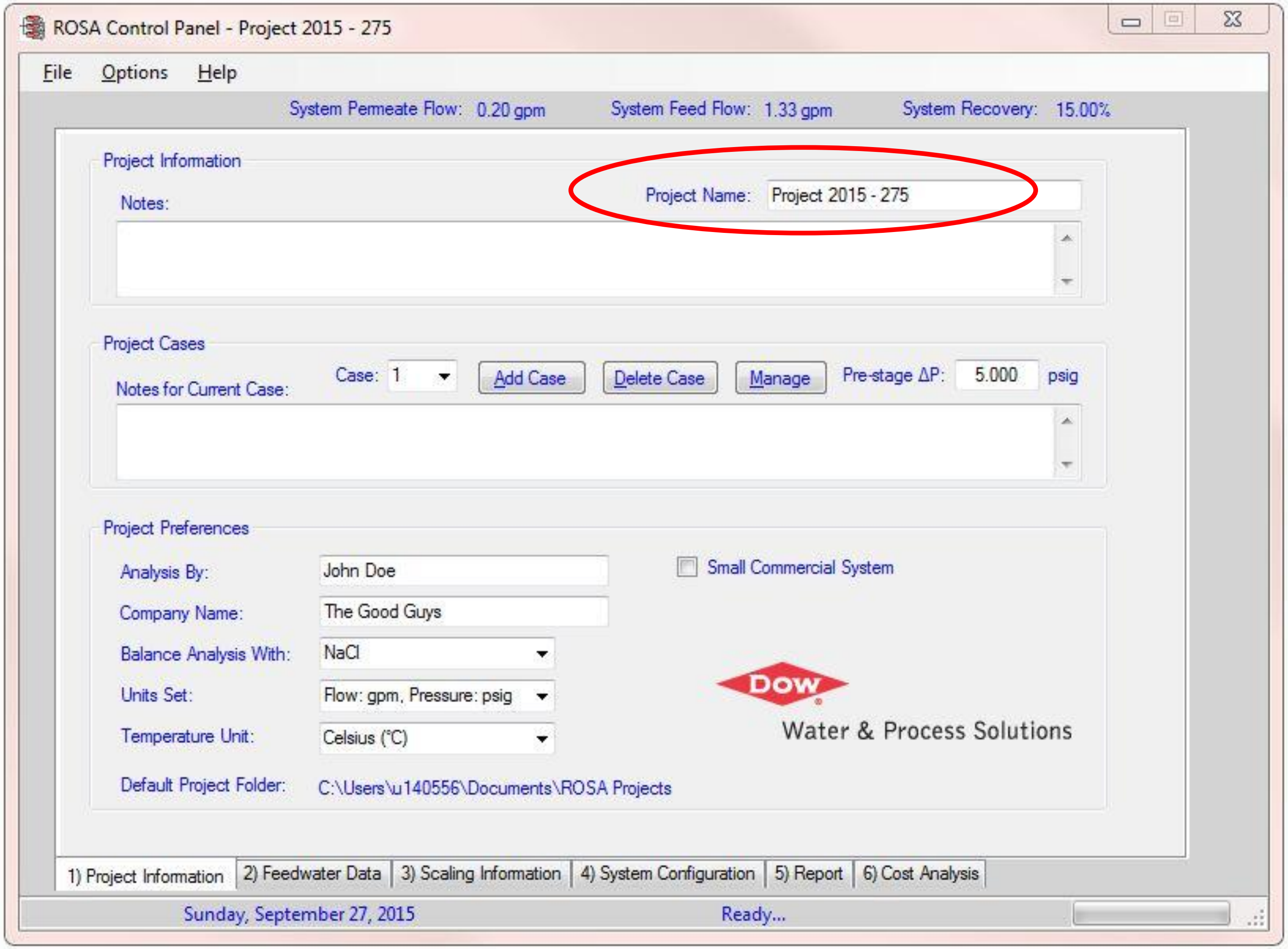
ROSA – Advanced RO Plant Design

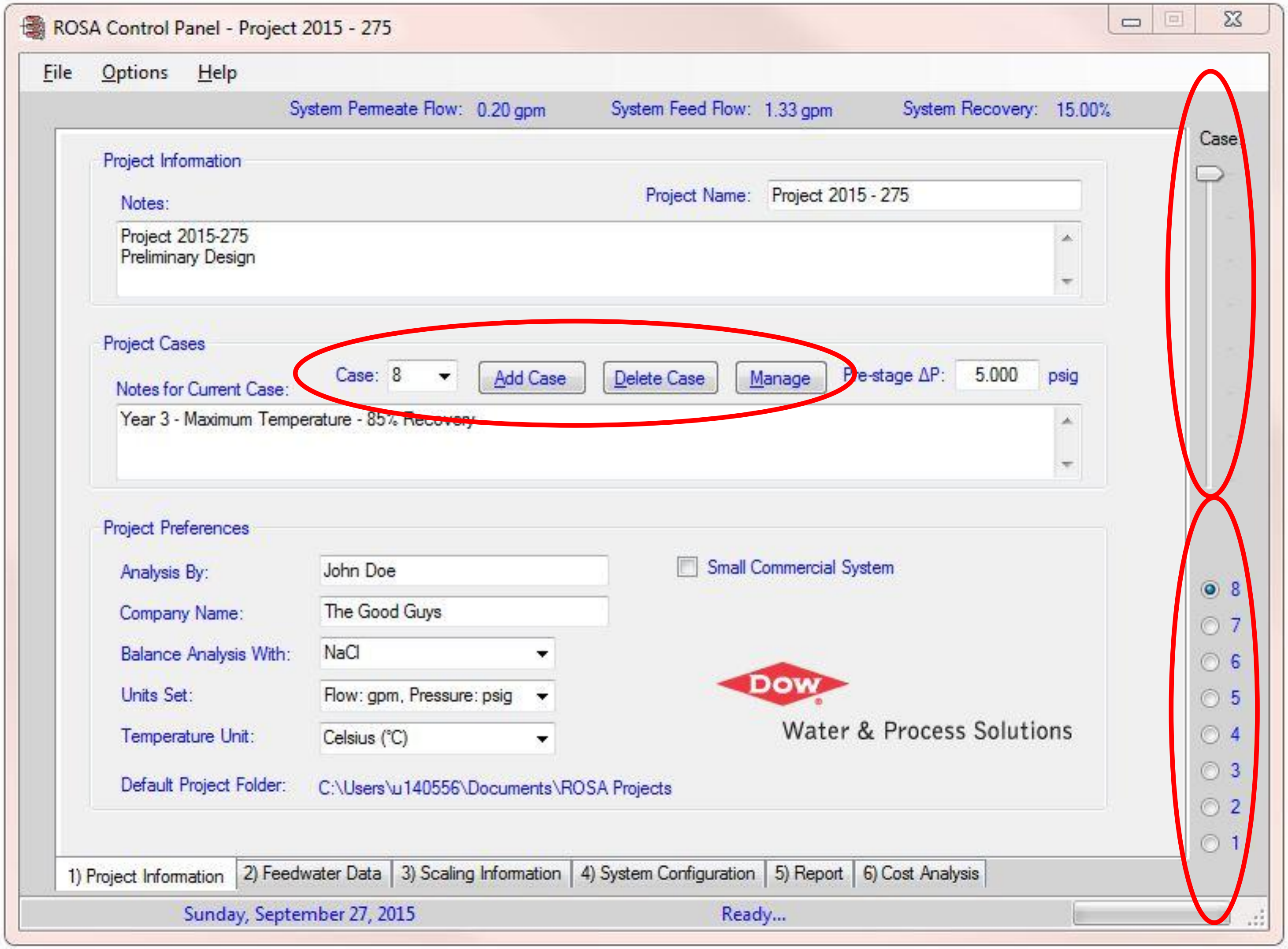
WATER ACADEMY

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

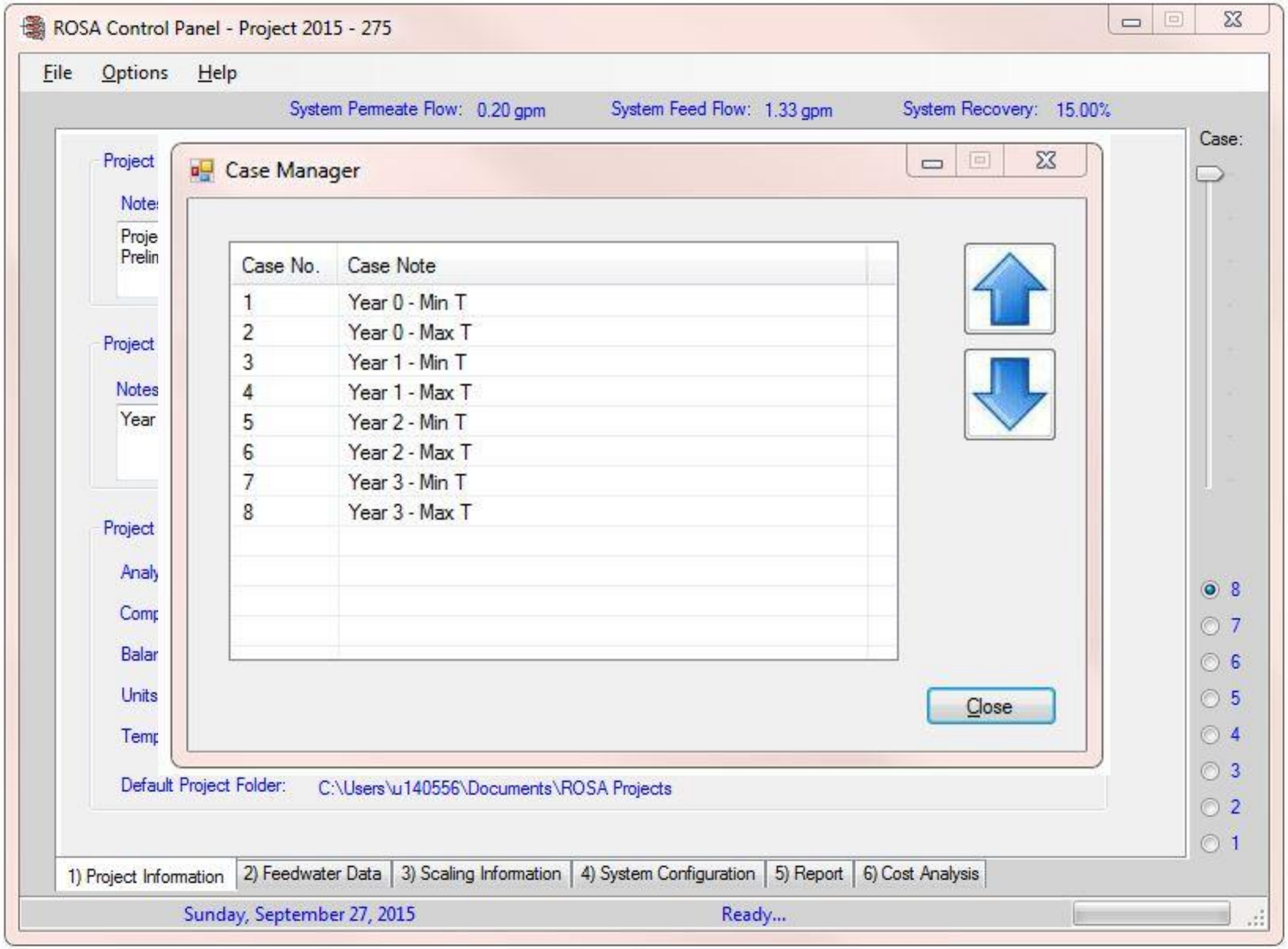
ROSA Basics: Name it and Save it!



ROSA Basics: Multi-Case File



ROSA Basics: Manage Case Order



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

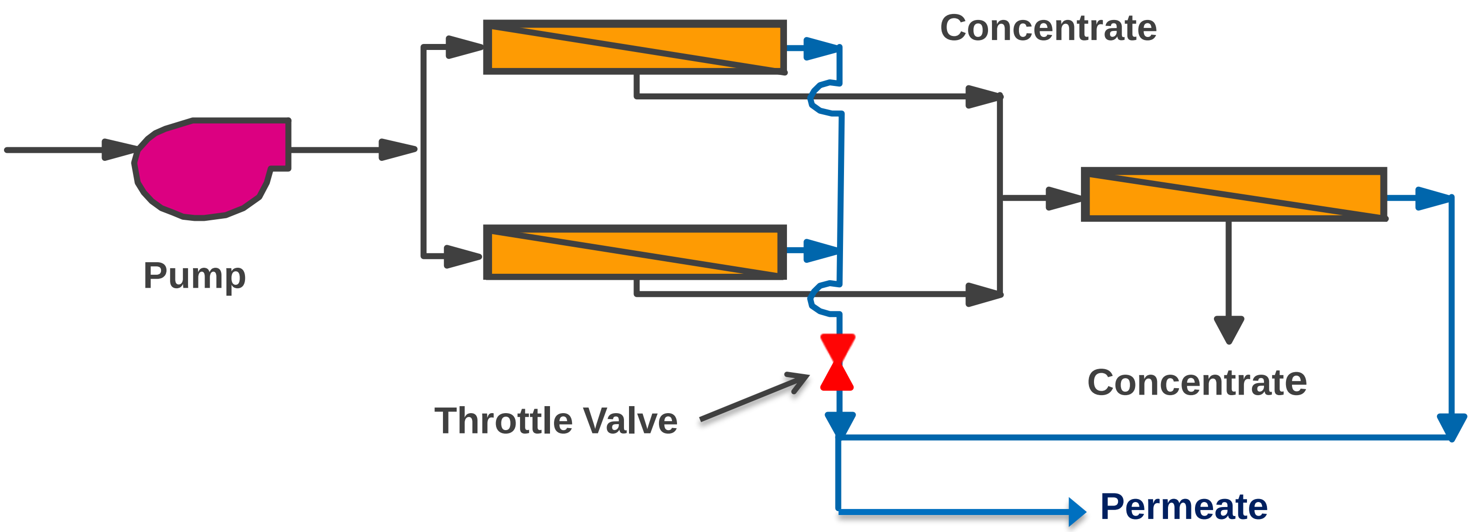
Managing Flux Balance

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

Managing Permeate Quality

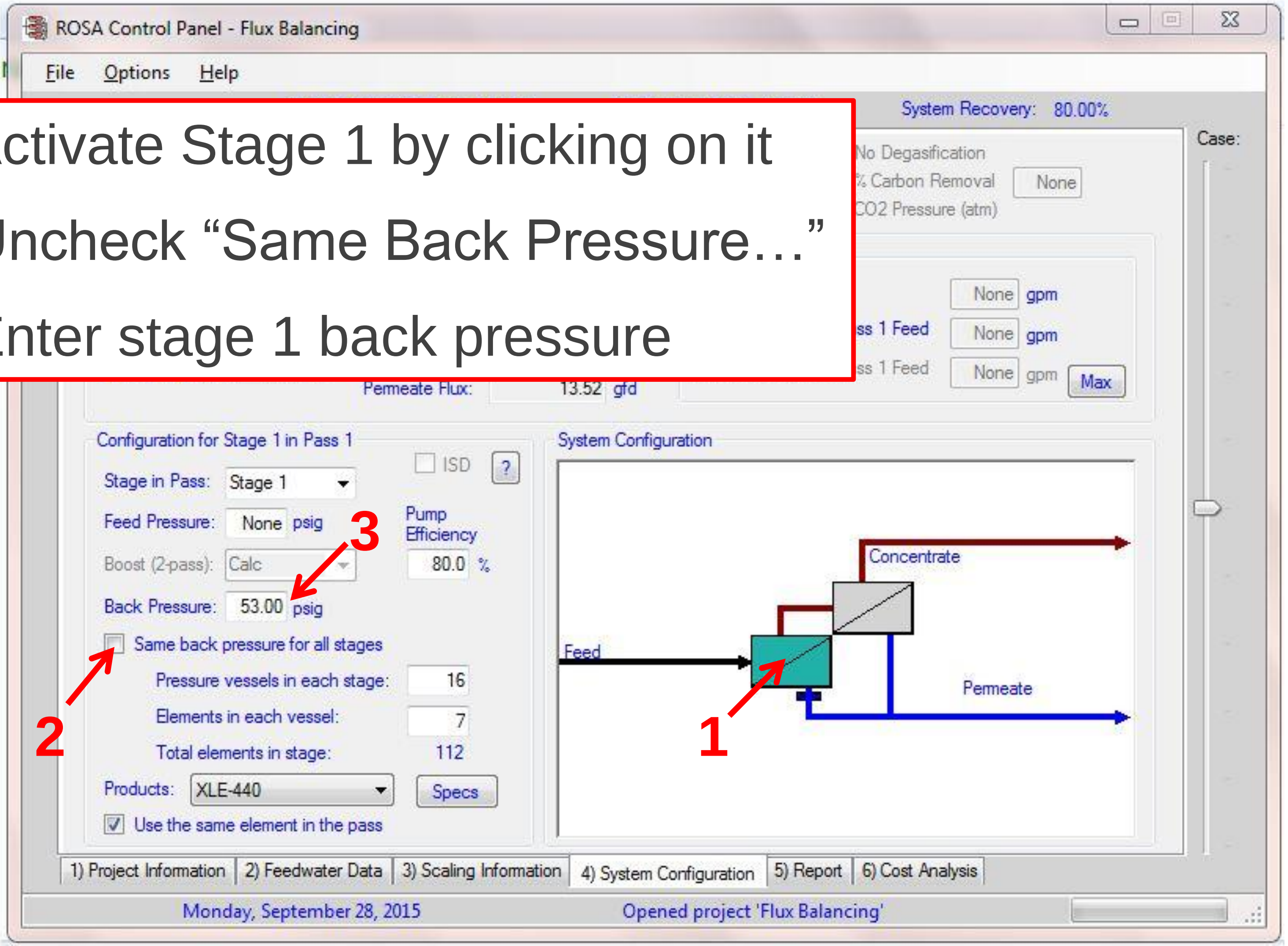
- RO with feed water/permeate blending
- 2 pass RO system
- 2 pass RO system w/ partial 2nd pass
- 2 pass RO system w/ permeate split design

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



WATER & PROCESS SOLUTIONS

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 ft²	Average Pass 1 Flux	13.52 gfd	Power		69.84 kW
Water Classification: Well Water SDI < 3				Specific Energy		1.68 kWh/kgal

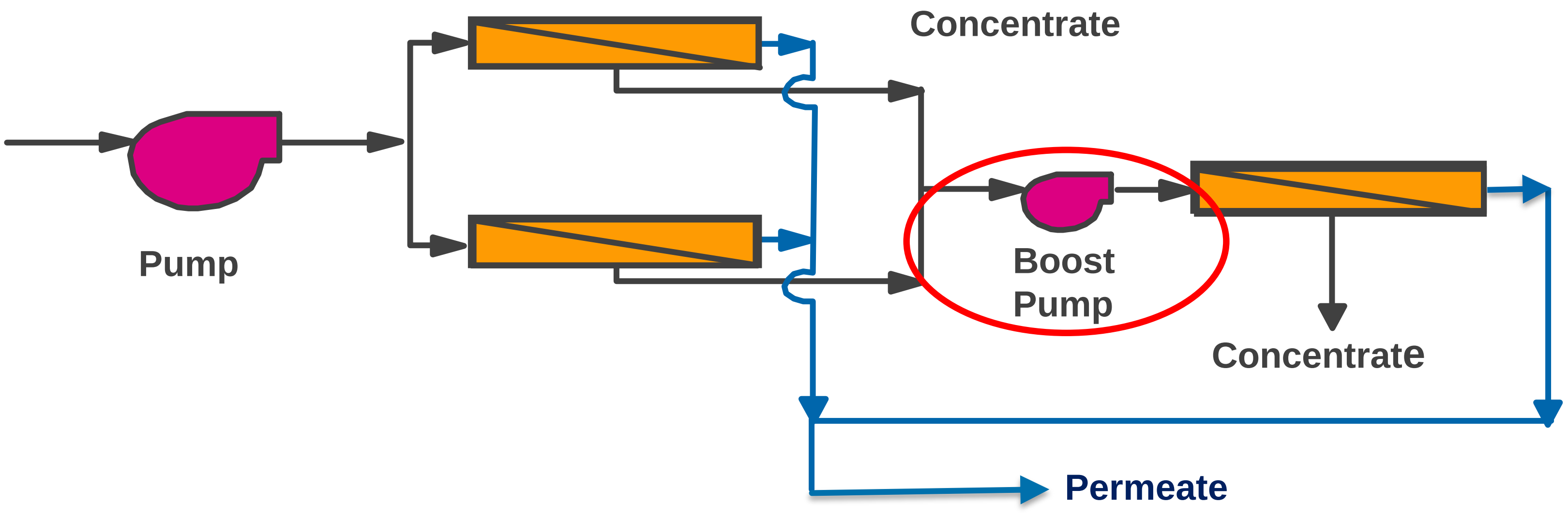
Stage	Element	#PV	#Ele	Feed Flow (gpm)	Feed Press (psig)	Recirc Flow (gpm)	Conc Flow (gpm)	Conc Press (psig)	Perm Flow (gpm)	Avg Flux (gfd)	Perm Press (psig)	Boost Press (psig)	Perm TDS (mg/l)
1	XLE-440	16	7	867.50	148.04	0.00	379.01	123.07	488.49	14.27	53.00	0.00	63.76
2	XLE-440	8	7	379.01	123.07	0.00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

Pass Streams (mg/l as Ion)

Name	Feed	Adjusted Feed	Concentrate		Permeate		
			Stage 1	Stage 2	Stage 1	Stage 2	Total
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

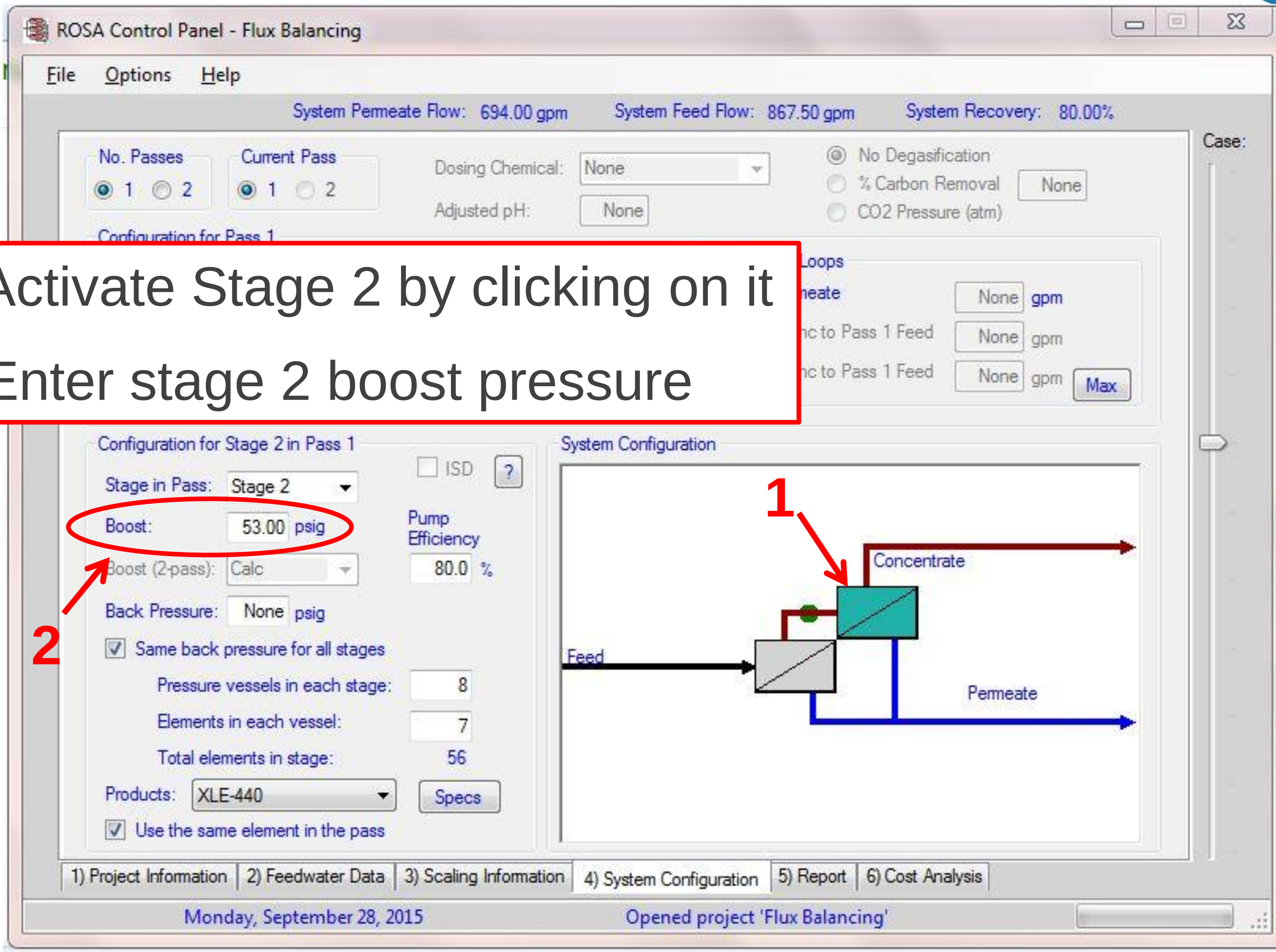


Boost pump can be driven electrically or by energy recovery device.

Adding Stage 2 Boost Pump

1. Activate Stage 2 by clicking on it

2. Enter stage 2 boost pressure



Stage 2 Boost Pressure - Report

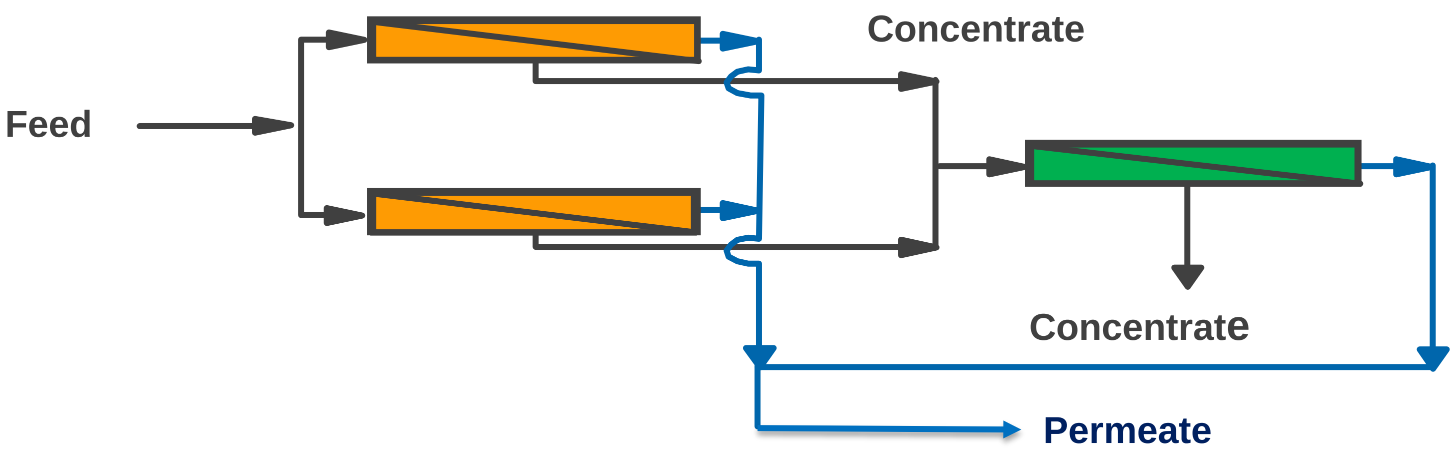
System Details

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 ft²	Average Pass 1 Flux	13.52 gfd	Power	59.44 kW
Water Classification: Well Water SDI < 3				Specific Energy	1.43 kWh/kgal

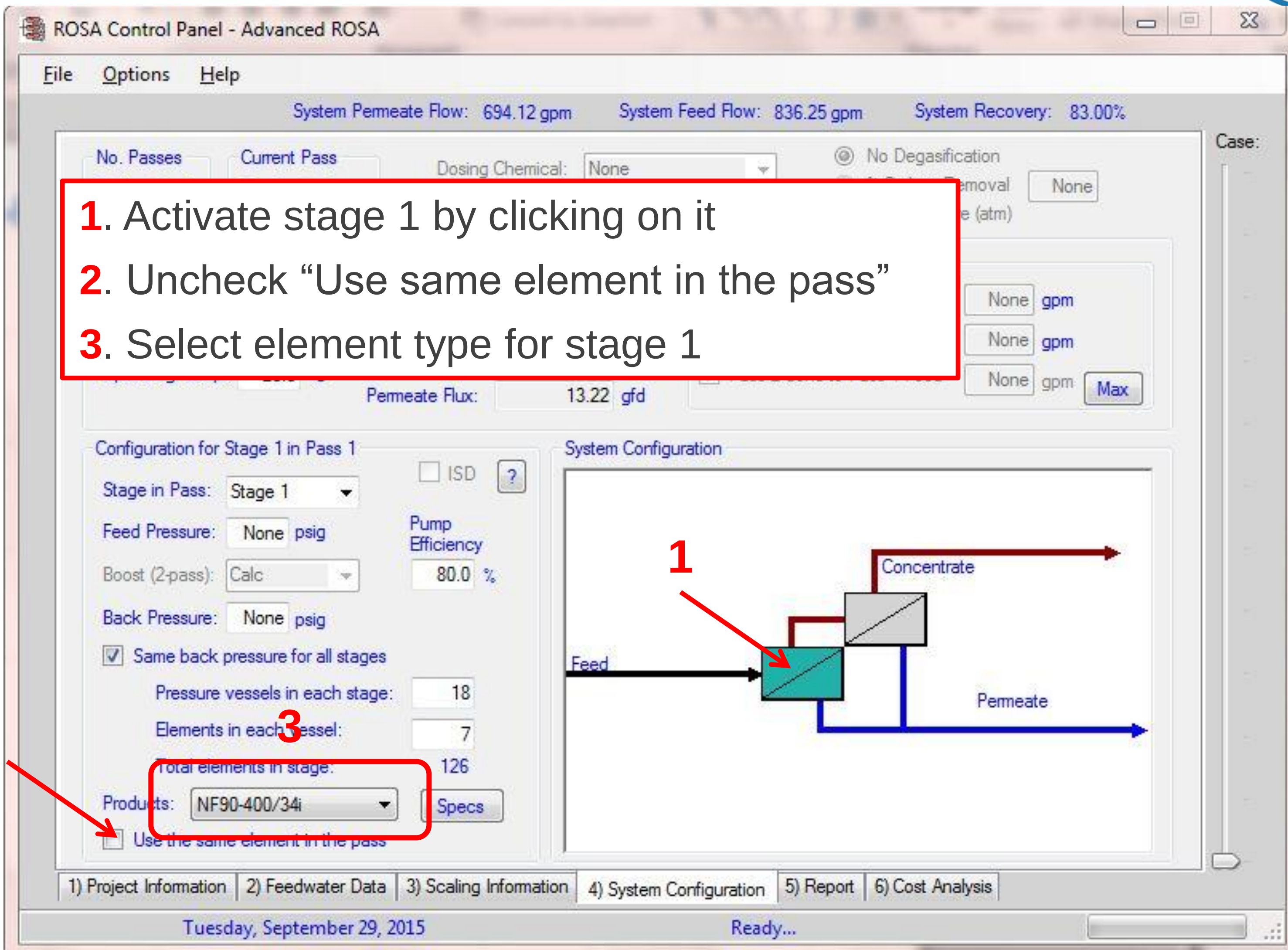
Stage	Element	#PV	#Ele	Feed Flow (gpm)	Feed Press (psig)	Recirc Flow (gpm)	Conc Flow (gpm)	Conc Press (psig)	Perm Flow (gpm)	Avg Flux (gfd)	Perm Press (psig)	Boost Press (psig)	Perm TDS (mg/l)
1	XLE-440	16	7	867.50	102.67	0.00	381.55	77.30	485.95	14.20	0.00	0.00	63.32
2	XLE-440	8	7	381.55	130.30	0.00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

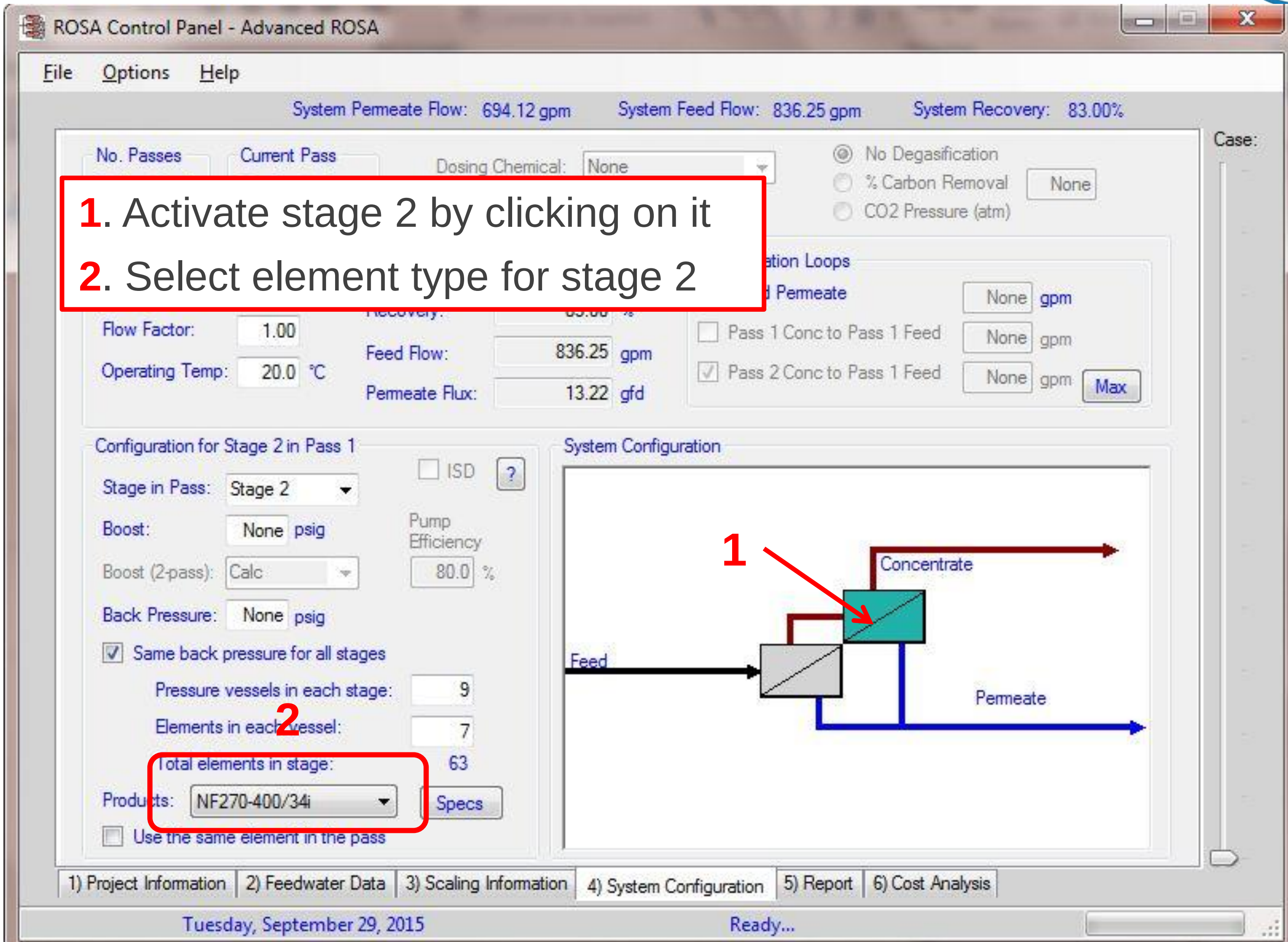
Multi-Element Hybrid Array



Multi-Element Hybrid Array - ROSA



Multi-Element Hybrid Array - ROSA



Using Multiple Elements in an Array

WATER ACADEMY

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		
			Stage 1	Stage 2	Stage 1	Stage 2	Total
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	0.00	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

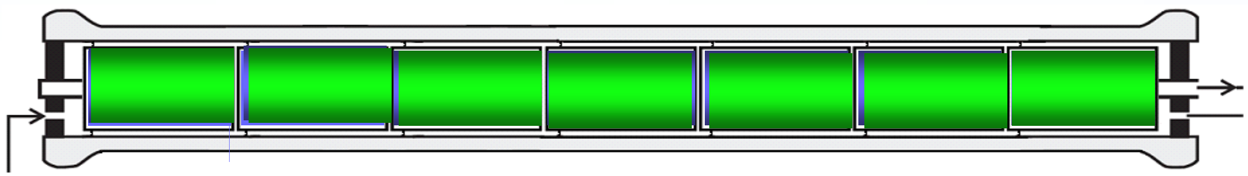
Increased Alk

Increased TDS

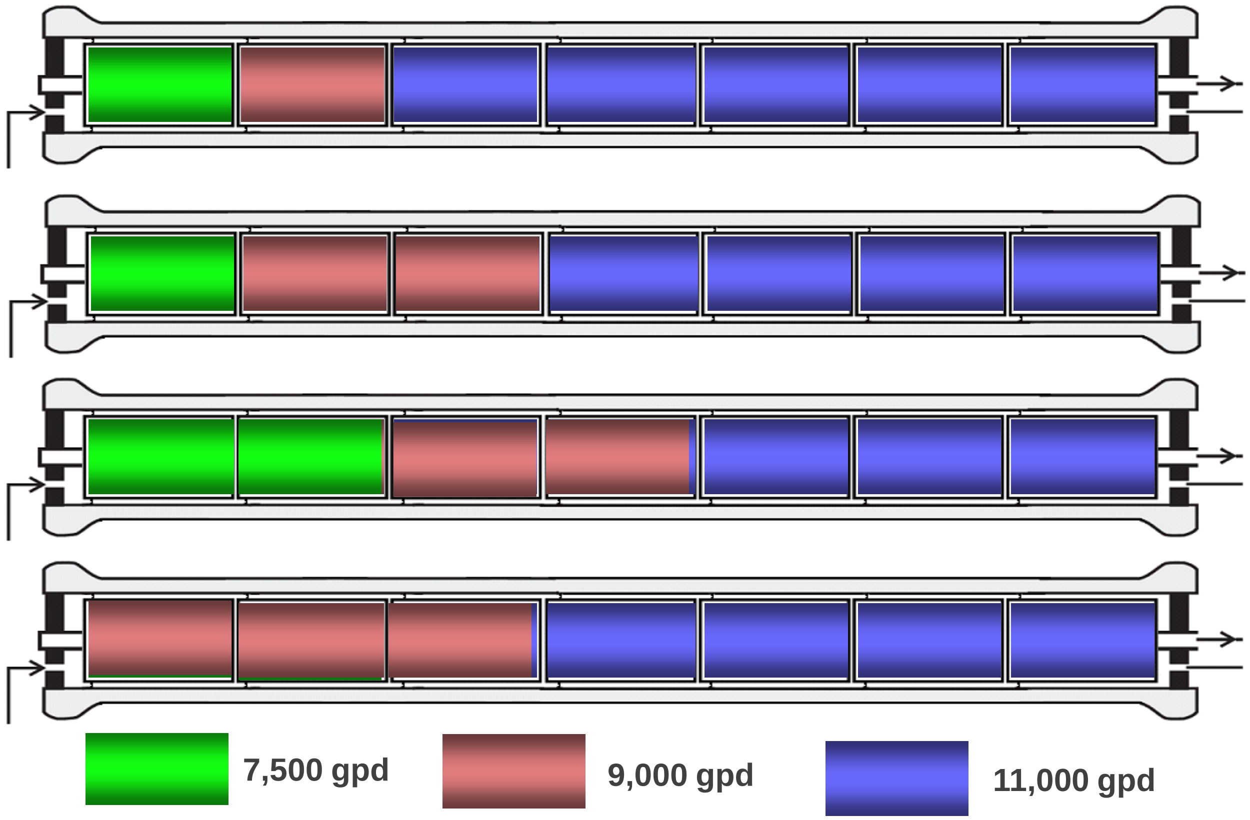
Design Warnings

-None-

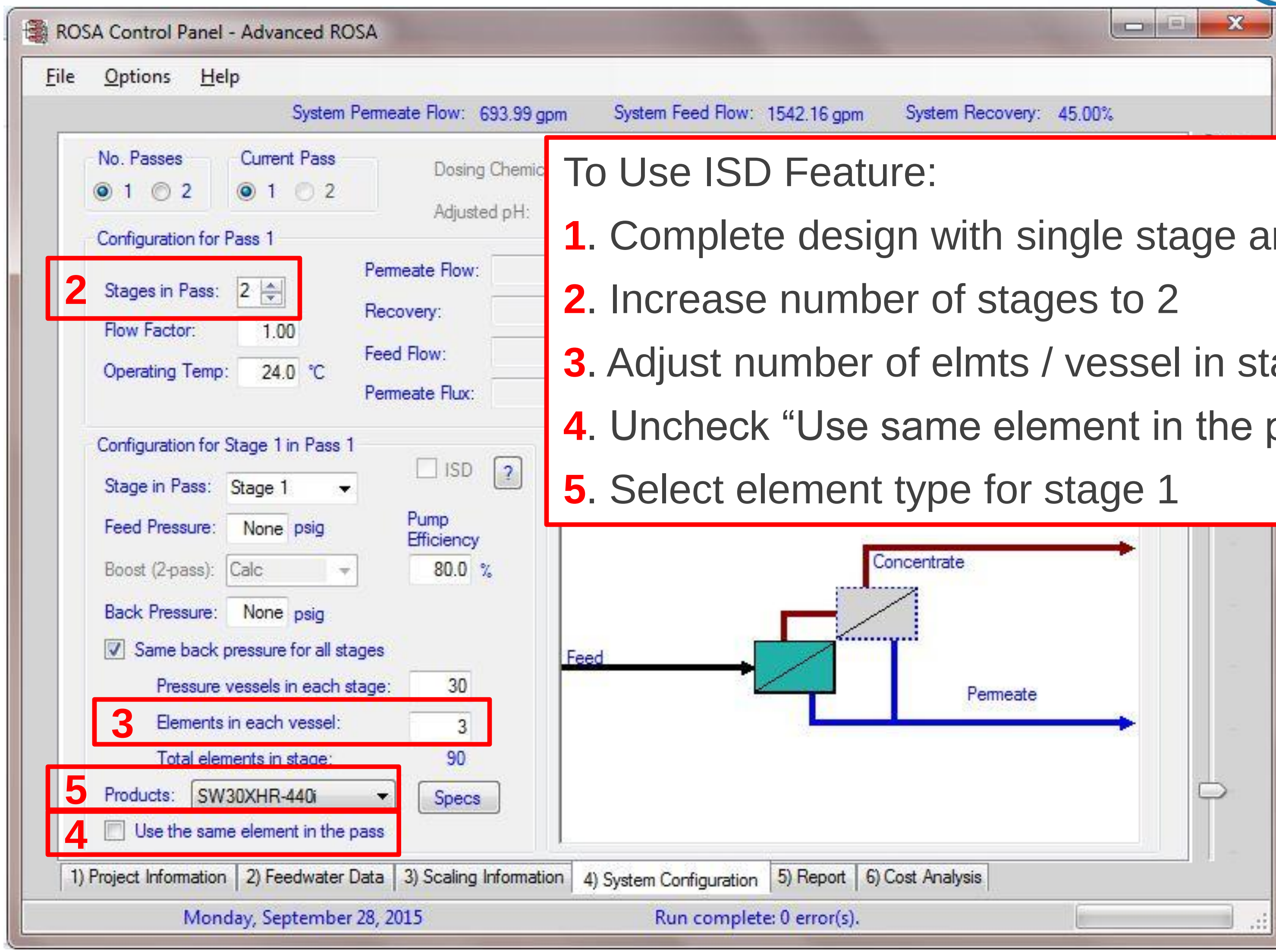
SWRO Internally Staged Array



Examples of Potential FILMTEC™ ISD Element Loading Options



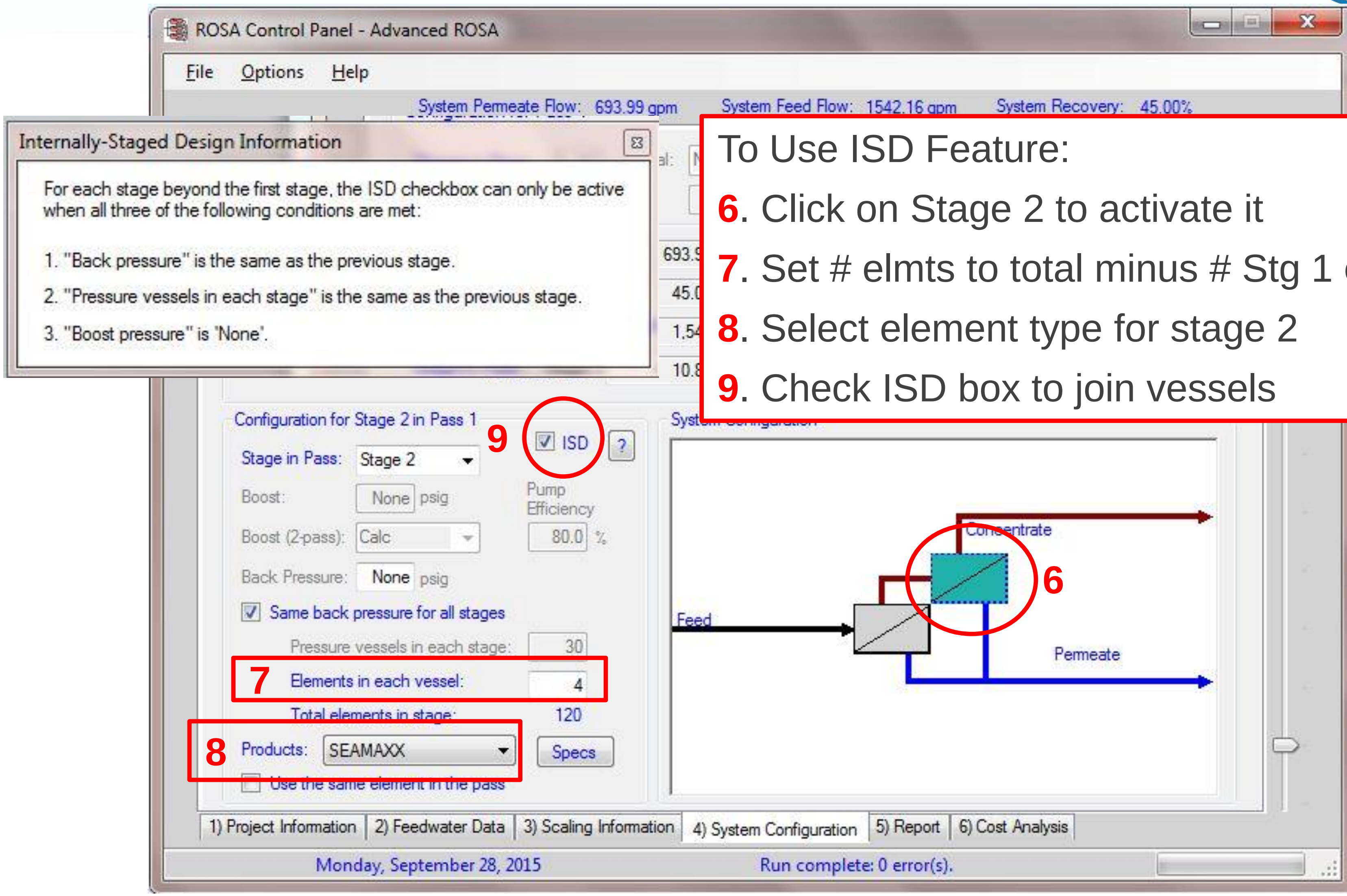
Internally Staged Design – Stage 1



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



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 - SW30XHR-440i - 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 ft²	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

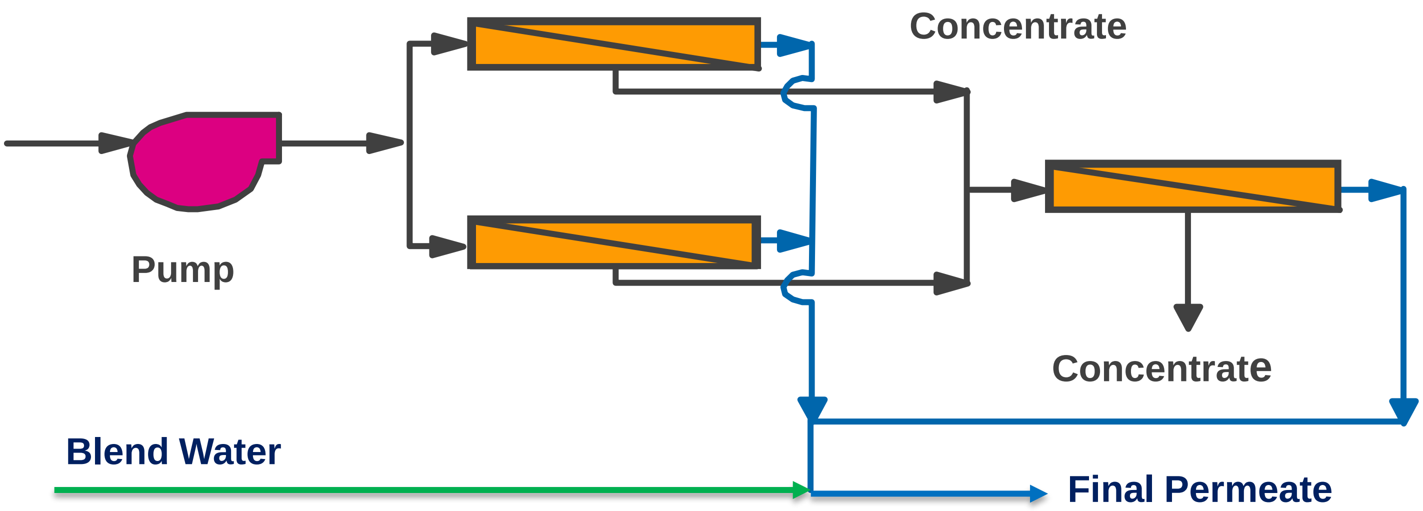
Stage	Element	#PV	#Ele	Feed Flow (gpm)	Feed Press (psig)	Recirc Flow (gpm)	Conc Flow (gpm)	Conc Press (psig)	Perm Flow (gpm)	Avg Flux (gfd)	Perm Press (psig)	Boost Press (psig)	Perm TDS (mg/l)
1	SW30XHR-440i	30	3	1542.16	795.30	0.00	1214.43	780.24	327.72	11.92	0.00	0.00	77.73
2	SEAMAXX	30	4	1214.43	780.24	0.00	848.16	767.47	366.27	9.99	0.00	0.00	475.29

Pass Streams (mg/l as Ion)							
Name	Feed	Adjusted Feed	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
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

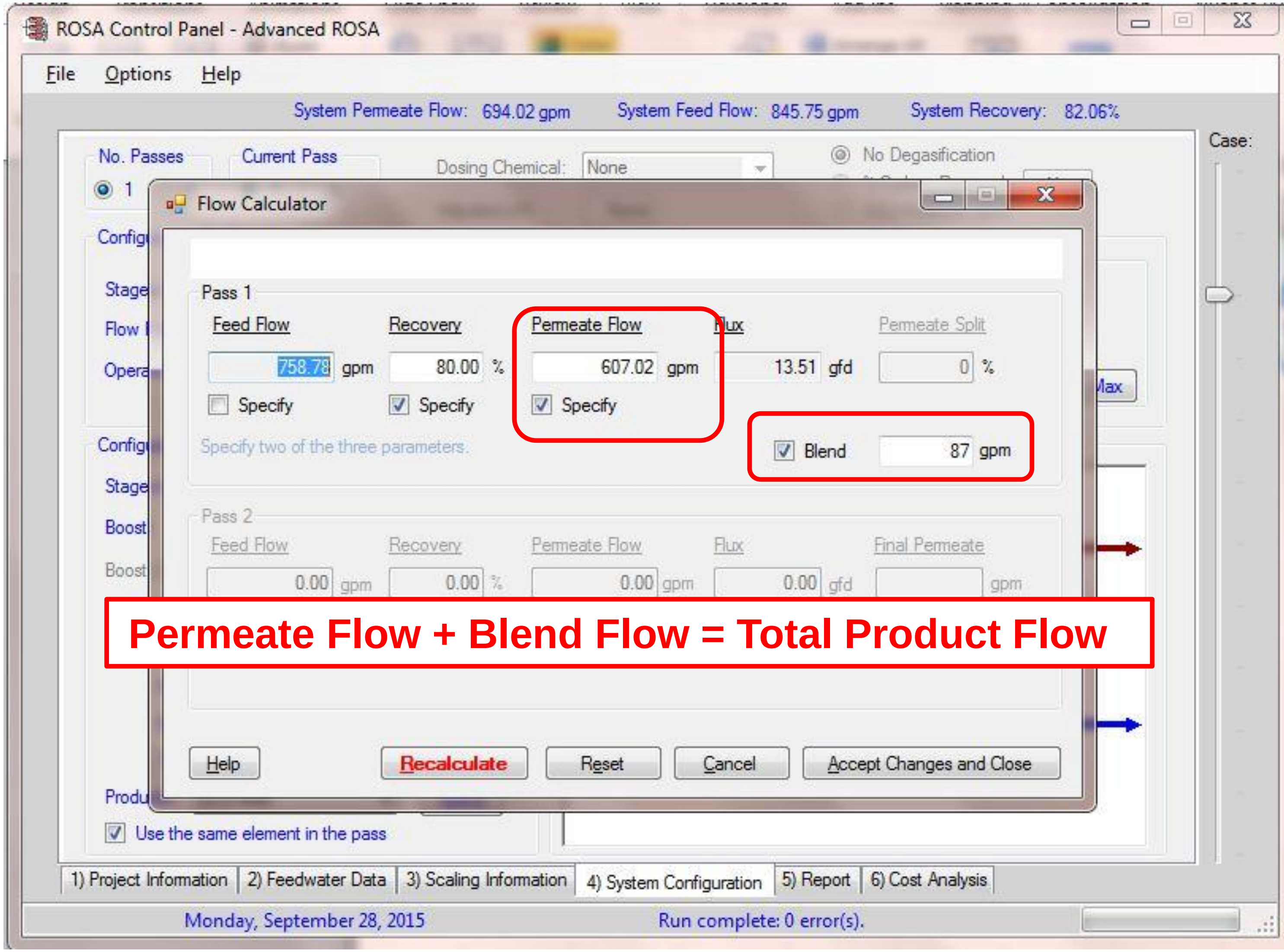
Design Warnings

-None-

RO with Feed Water Blending



RO with Feed Water Blending



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 ft²	Average Pass 1 Flux	13.51 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		

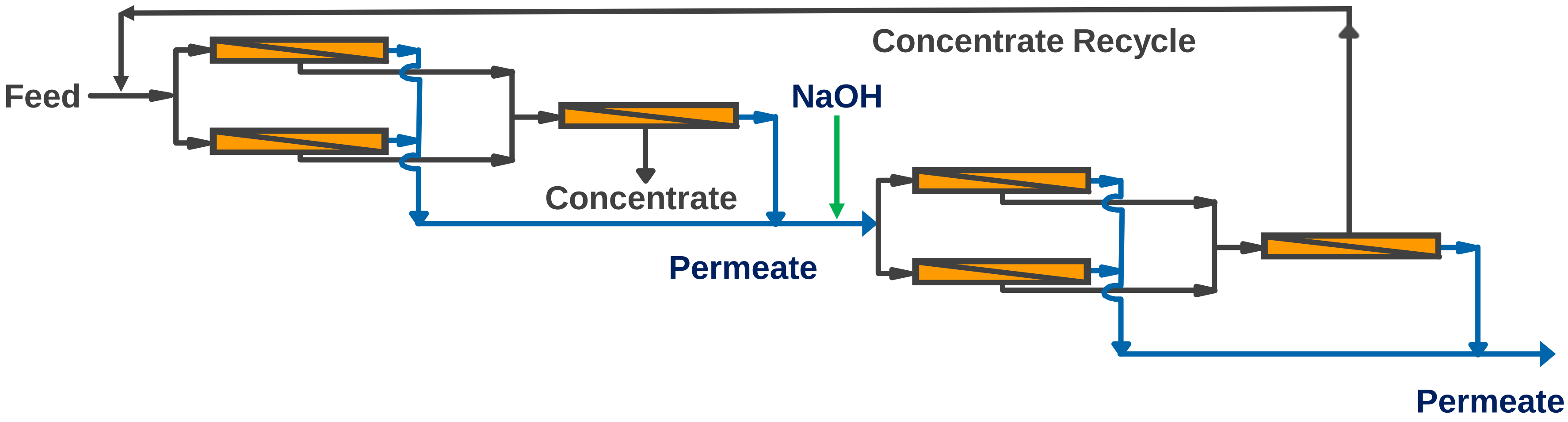
Stage	Element	#PV	#Ele	Feed Flow (gpm)	Feed Press (psig)	Recirc Flow (gpm)	Conc Flow (gpm)	Conc Press (psig)	Perm Flow (gpm)	Avg Flux (gfd)	Perm Press (psig)	Boost Press (psig)	Perm TDS (mg/l)
1	ECO-440i	14	7	758.75	109.63	0.00	279.69	97.31	479.06	16.00	0.00	0.00	11.28
2	ECO-440i	7	7	279.69	97.31	0.00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

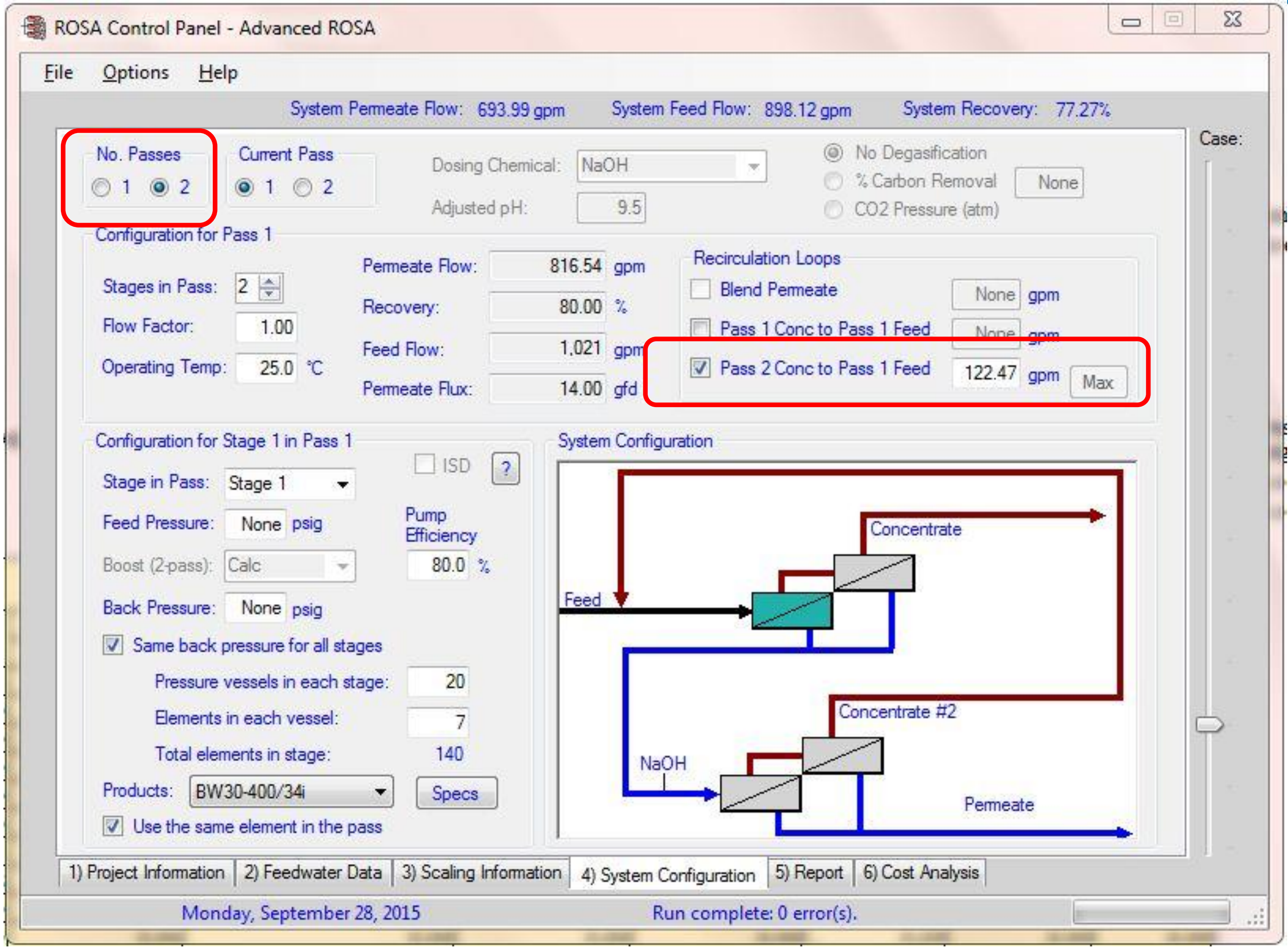
Design Warnings

-None-

2 Pass RO

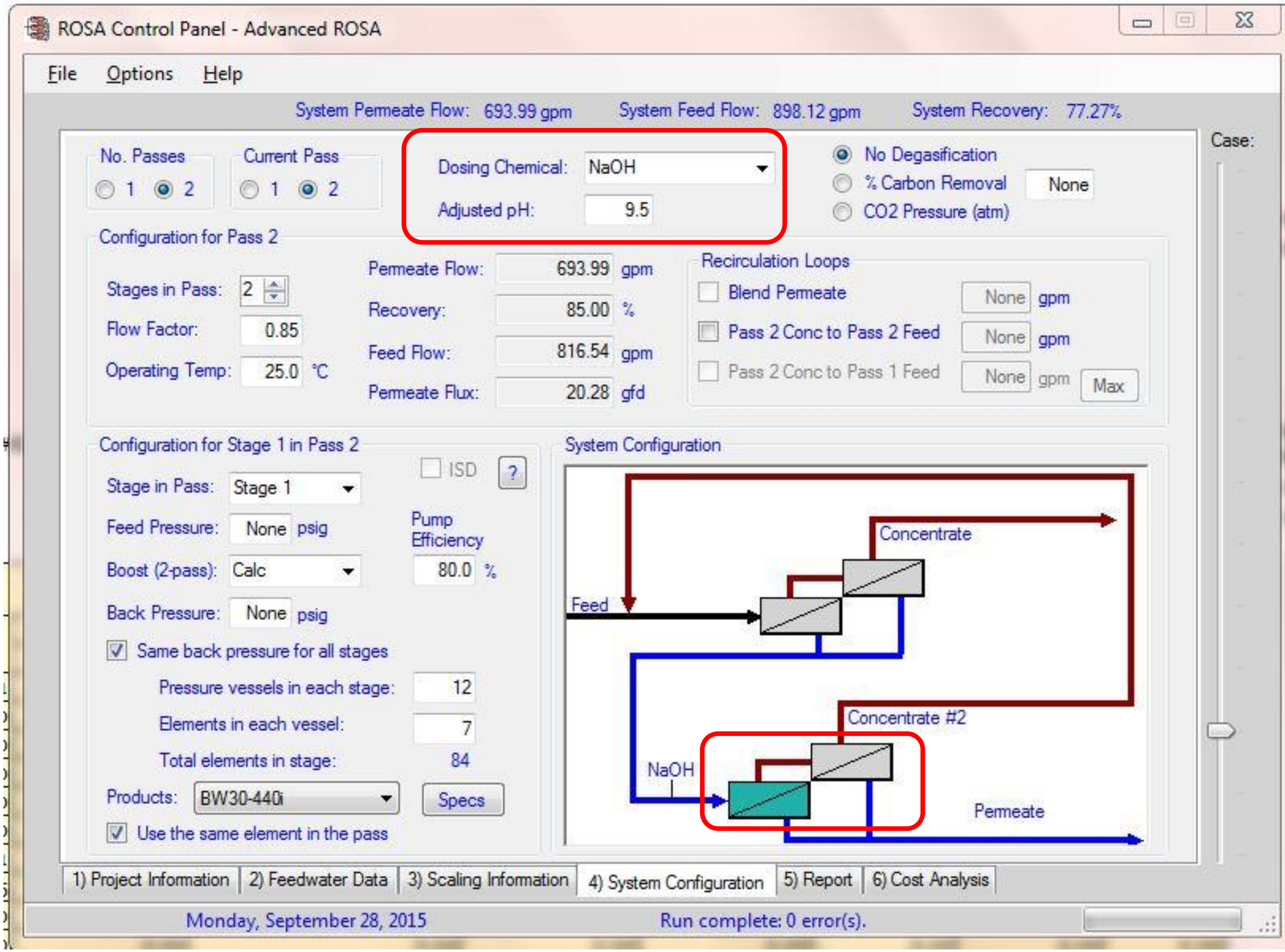

Concentrate Recycle
Feed
NaOH
Concentrate
Permeate
Permeate

2 Pass RO – Pass 1

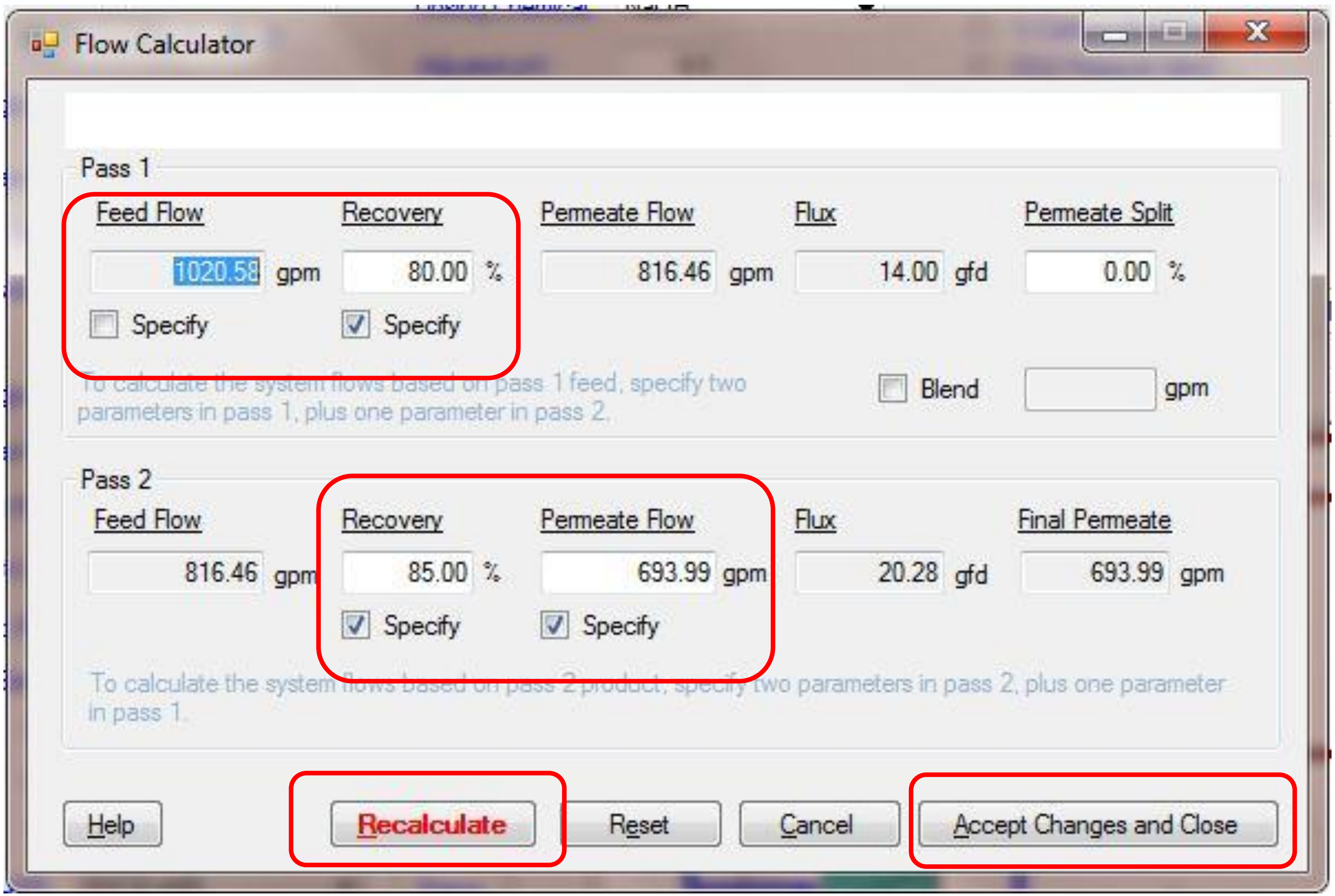


WATER & PROCESS SOLUTIONS

2 Pass RO – Pass 2



2 Pass RO – Flow Calculator



2 Pass RO – Pass 1 ROSA Report

WATER ACADEMY

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 ft²	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

Pass Streams (mg/l as Ion)

Name	Feed	Adjusted Feed		Concentrate		Permeate		
		Initial	After Recycles	Stage 1	Stage 2	Stage 1	Stage 2	Total
NH4+ + NH3	0.11	0.11	0.10	0.26	0.49	0.01	0.01	0.01
K	10.00	10.00	8.95	23.10	44.02	0.11	0.43	0.18
Na	443.00	443.00	398.39	1028.58	1960.65	4.82	18.51	7.98
Mg	70.00	70.00	62.13	160.96	308.11	0.41	1.51	0.66
Ca	160.00	160.00	141.98	367.89	704.25	0.90	3.38	1.47
Sr	1.80	1.80	1.60	4.14	7.92	0.01	0.04	0.02
Ba	0.01	0.01	0.01	0.02	0.04	0.00	0.00	0.00
CO3	1.65	1.65	2.28	9.85	25.05	0.00	0.00	0.00
HCO3	200.00	200.00	182.94	463.91	871.22	2.56	9.15	4.08
NO3	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	13.96
F	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	1.01
SiO2	12.00	12.00	10.67	27.62	52.82	0.09	0.31	0.14
Boron	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	3.05
TDS	1992.98	2003.33	1793.34	4632.16	8837.60	17.95	68.03	29.49
pH	7.80	7.80	8.00	8.02	7.96	6.22	6.44	6.32

2 Pass RO – Pass 2 ROSA Report

Case-specific: 2 Pass RO

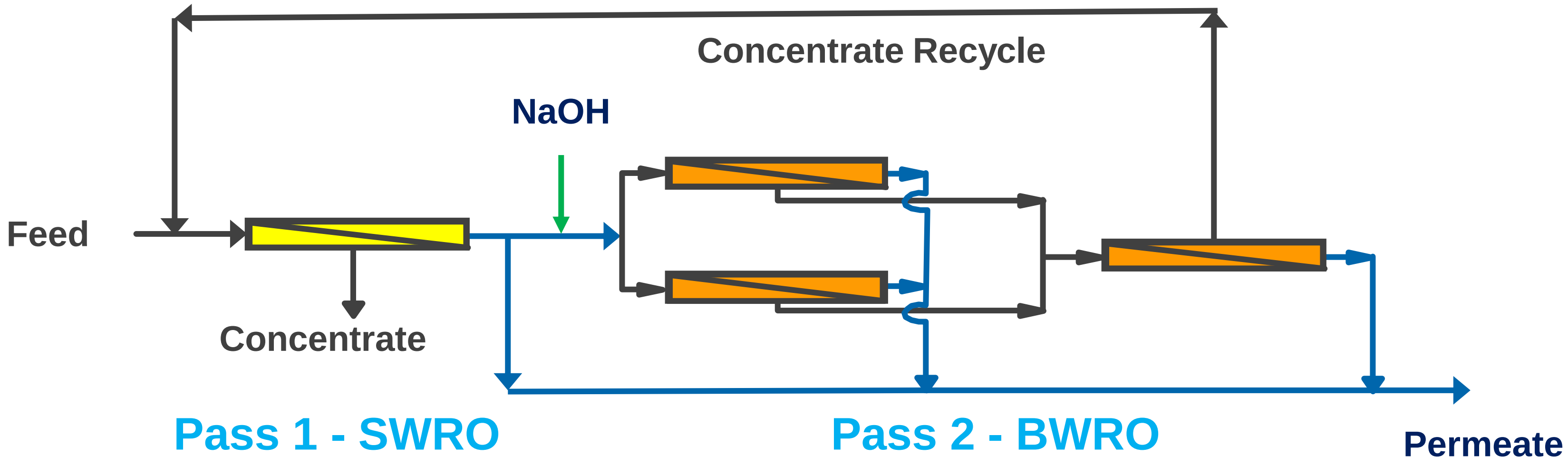
System Details -- Pass 2

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	49280.00 ft²	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 %				

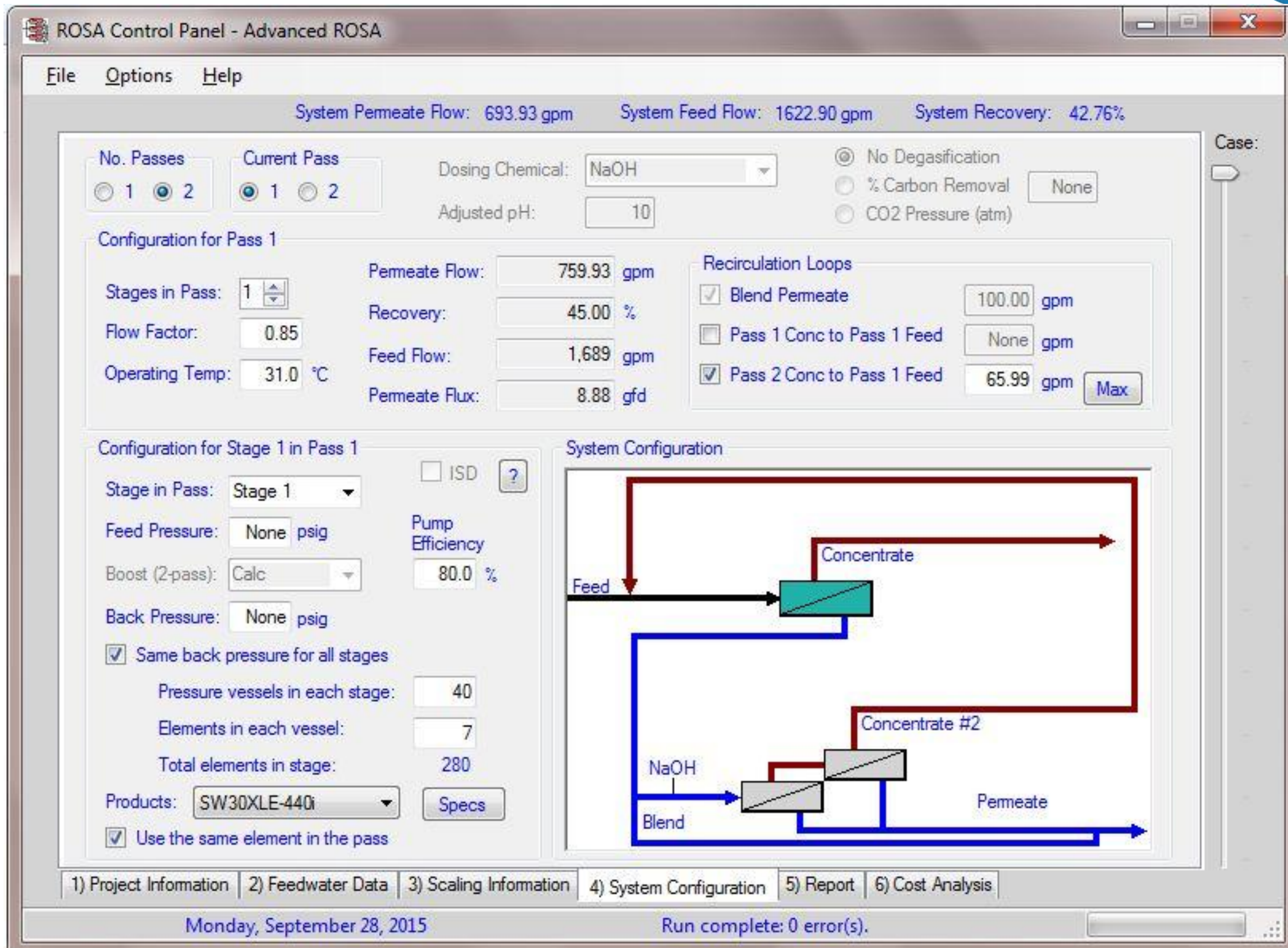
Stage	Element	#PV	#Ele	Feed Flow (gpm)	Feed Press (psig)	Recirc Flow (gpm)	Conc Flow (gpm)	Conc Press (psig)	Perm Flow (gpm)	Avg Flux (gfd)	Perm Press (psig)	Boost Press (psig)	Perm TDS (mg/l)
1	BW30-440i	12	7	816.56	202.72	0.00	274.13	168.99	542.43	21.13	0.00	0.00	0.17
2	BW30-440i	4	7	274.13	168.99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

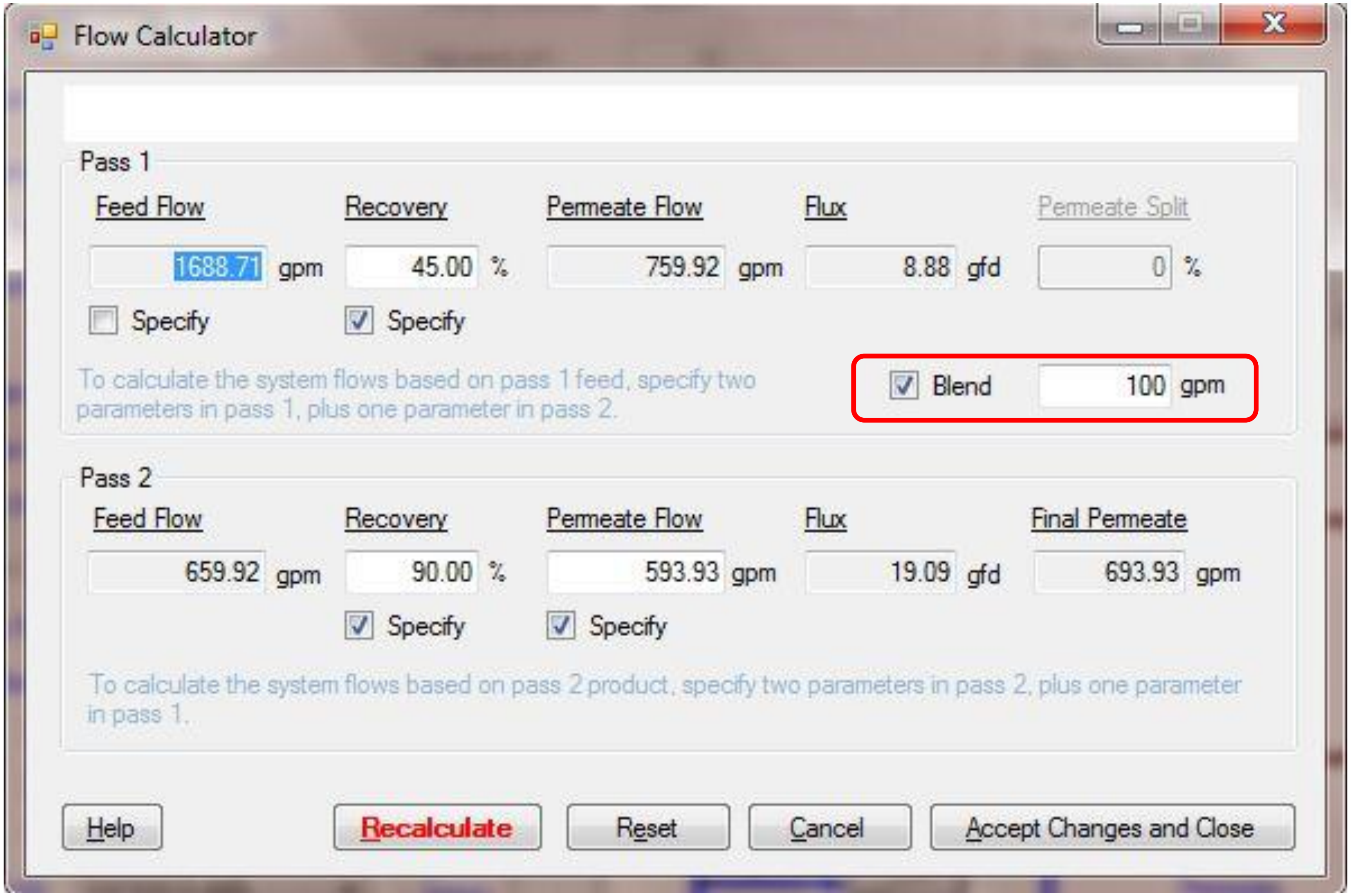
2 Pass RO with Partial 2nd Pass



2 Pass RO with Partial 2nd Pass



2 Pass RO with Partial 2nd Pass



Pass 2 Permeate Flow + Blend Flow = Final Permeate Flow

2 Pass RO with Partial 2nd 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 ft²	~~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 2nd Pass - ROSA

System Details -- Pass 2

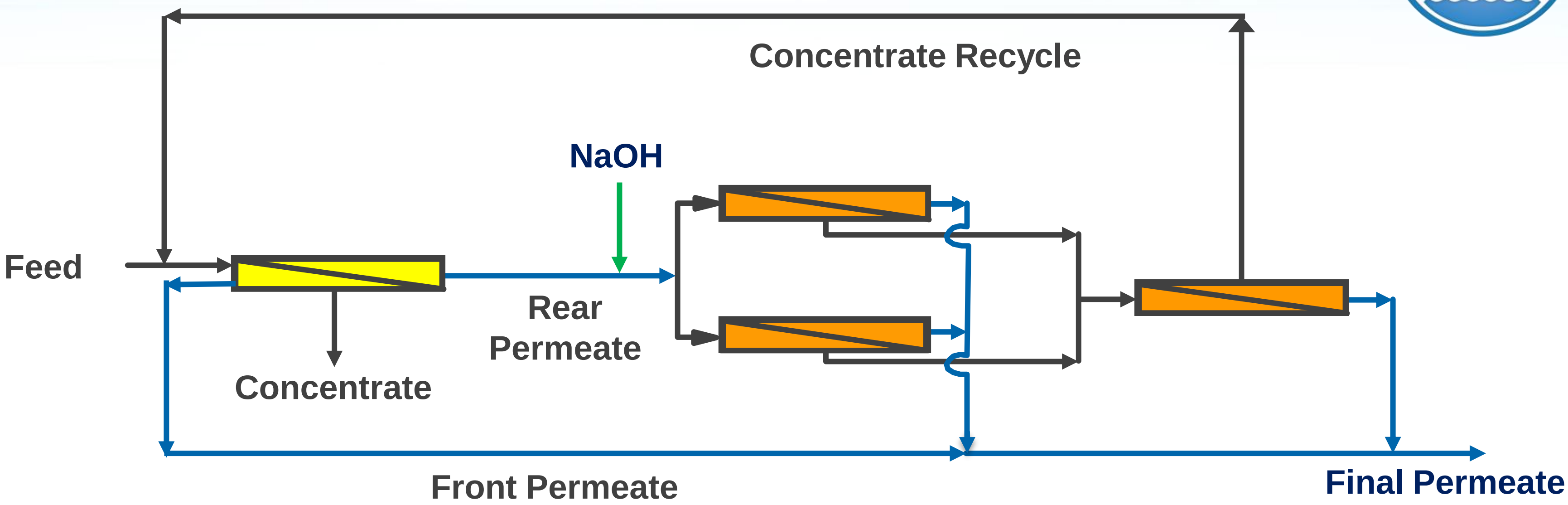
Feed Flow to Stage 1	660.01 gpm	Pass 2 Permeate Flow	593.83 gpm	Osmotic Pressure:	
Raw Water Flow to System	1622.90 gpm	Pass 2 Recovery	89.97 %	Feed	4.12 psig
Feed Pressure	89.38 psig	Feed Temperature	31.0 C	Concentrate	38.44 psig
Flow Factor	0.90	Feed TDS	346.03 mg/l	Average	21.28 psig
Chem. Dose (100% NaOH)	9.58 mg/l	Number of Elements	112	Average NDP	68.61 psig
Total Active Area	44800.00 ft²	Average Pass 2 Flux	19.09 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 ()	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	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)

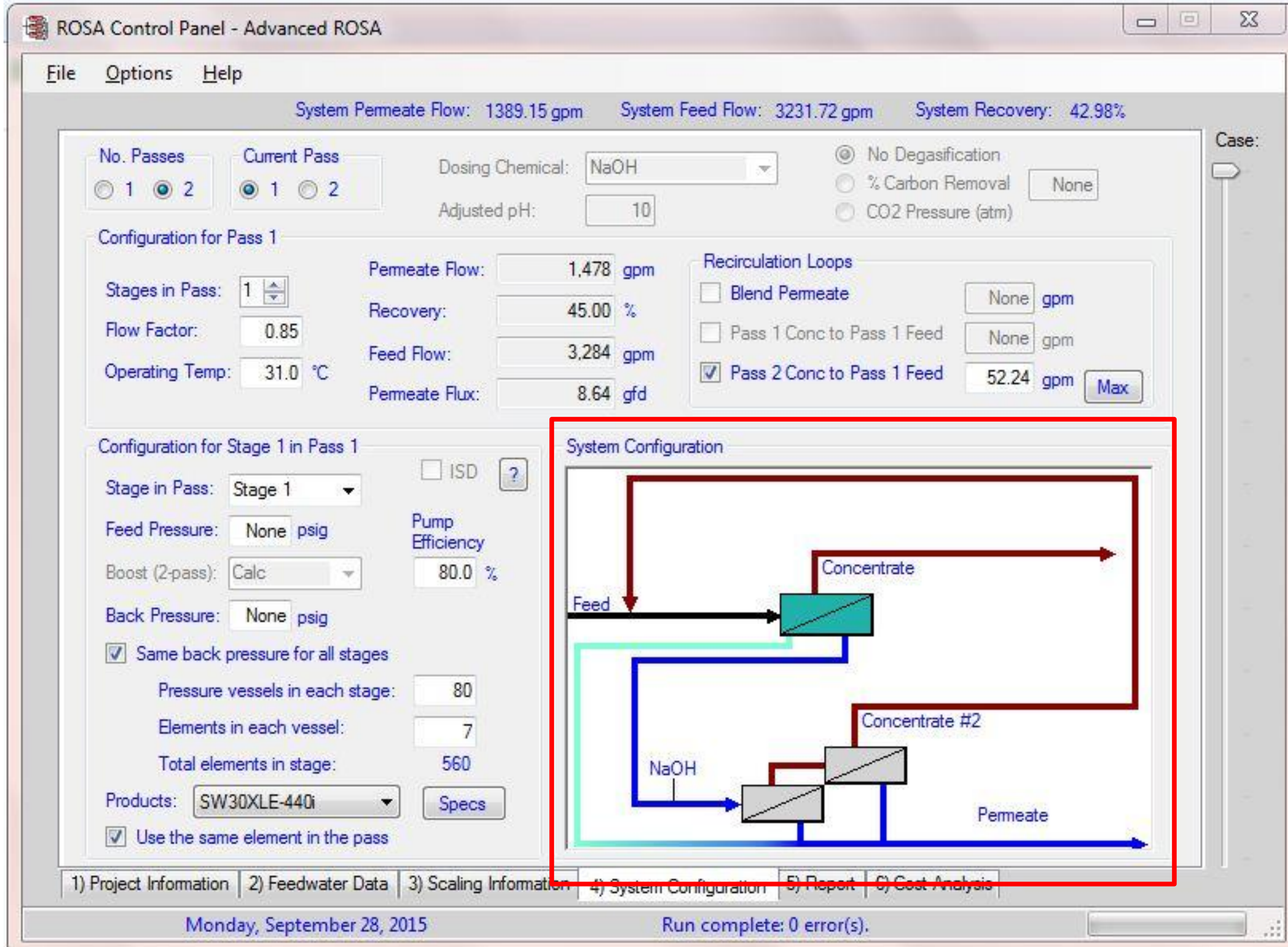
Name	Feed	Adjusted Feed	Concentrate		Permeate			
			Stage 1	Stage 2	Stage 1	Stage 2	Total	Blended Total
NH4+ + NH3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	4.10	4.10	15.13	38.16	0.18	0.86	0.31	0.85
Na	125.61	131.11	493.08	1269.92	2.55	11.84	4.22	21.71
Mg	0.17	0.17	0.64	1.67	0.00	0.00	0.00	0.03
Ca	0.34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

Split Permeate SWRO with Partial 2 Pass Design

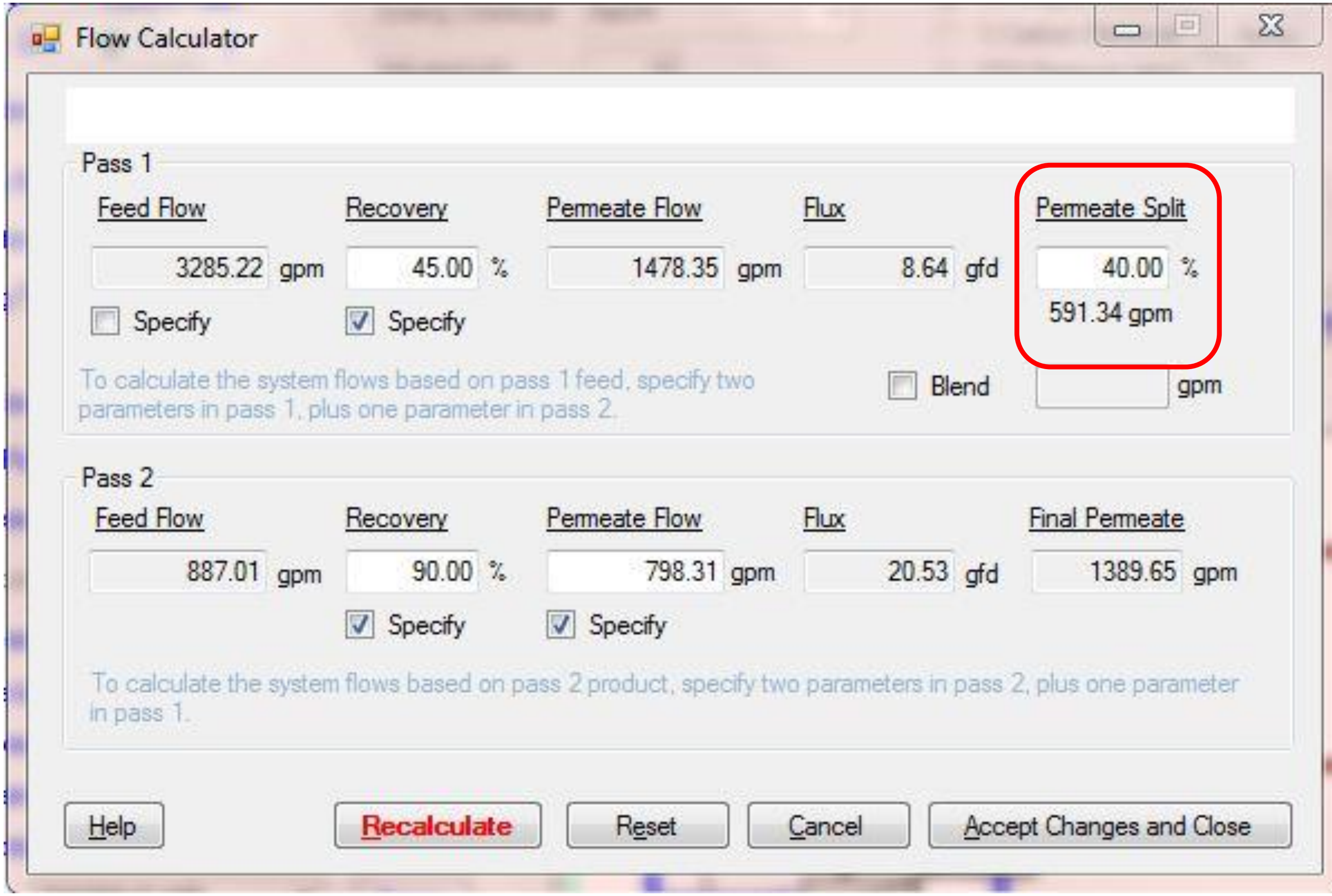


- Split permeate SWRO systems withdraw permeate from both ends of the first pass pressure vessels
- Front permeate is lower in salinity and is directly blended into the final permeate stream
- Many split permeate SWRO systems use ISD with elements chosen specifically to reduce front permeate TDS and/or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

Split Permeate SWRO with Partial 2 Pass Design



Split Permeate SWRO – Flow Calculator



Split Permeate SWRO – Pass 1 ROSA Report

WATER ACADEMY

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 ft²	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 ()	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

Pass Streams (mg/l as Ion)								
Name	Feed	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
K	405.00	405.00	400.67	490.85	726.85	1.74	6.13	6.13
Na	14800.00	14801.49	14640.22	17937.48	26579.91	54.31	187.23	187.23
Mg	213.00	213.00	210.33	257.86	383.29	0.08	0.25	0.25
Ca	440.00	440.00	434.49	532.67	791.78	0.15	0.51	0.51
Sr	5.61	5.61	5.54	6.79	10.10	0.00	0.01	0.01
Ba	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
HCO3	142.40	142.40	139.63	170.10	249.53	1.01	3.06	3.06
NO3	0.24	0.24	0.24	0.29	0.42	0.01	0.03	0.03
Cl	22192.65	22192.65	21950.81	26893.95	39846.94	84.16	290.46	290.46
F	0.57	0.57	0.56	0.69	1.02	0.00	0.01	0.01
SO4	3100.00	3100.00	3061.35	3753.05	5577.96	1.52	4.96	4.96
SiO2	4.00	4.00	3.96	4.85	7.17	0.02	0.08	0.08
Boron	4.61	4.61	4.77	5.68	7.57	0.74	1.80	1.80
CO2	0.62	0.62	0.57	0.75	1.27	0.44	0.57	0.57
TDS	41353.96	41355.45	40900.42	50112.80	74266.70	147.22	503.04	503.04
pH	8.00	8.00	8.03	7.99	8.00	6.49	6.82	6.82

Split Permeate SWRO – Pass 2 ROSA Report

Case-specific: Split Permeate 2 Pass RO

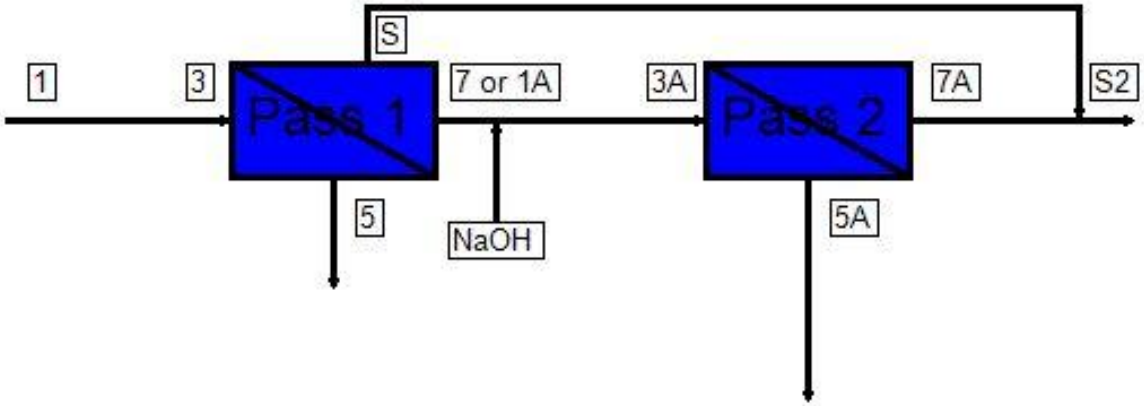
System Details -- Pass 2

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 ft²	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

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

Split Permeate SWRO –Overview ROSA Report



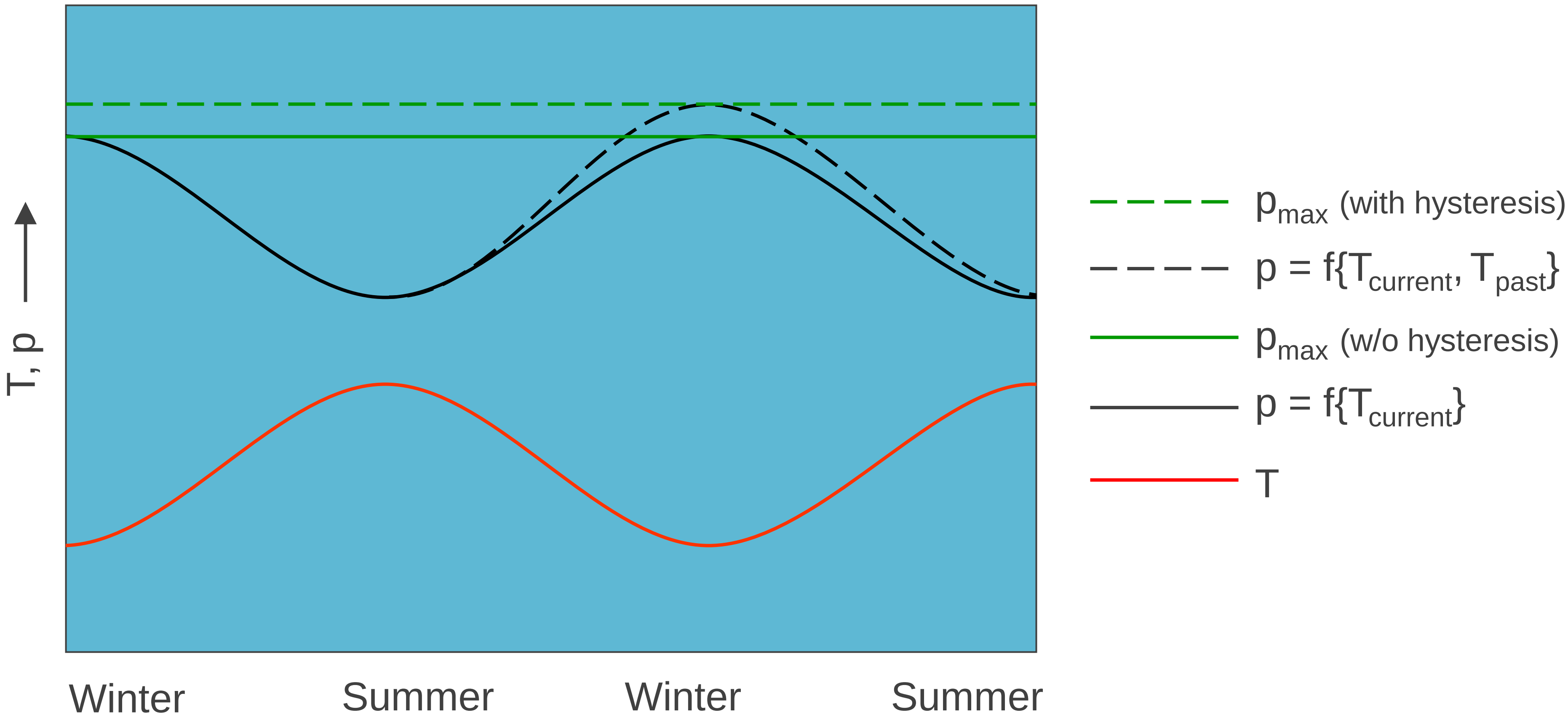
Pass 1				Pass 2			
Stream #	Flow (gpm)	Pressure (psig)	TDS (mg/l)	Stream #	Flow (gpm)	Pressure (psig)	TDS (mg/l)
1	3285.22	0.00	41353.96	1A	1478.31	-	506.86
3	3285.22	911.19	41355.45	3A	887.01	104.67	515.95
5	1806.92	894.43	74893.91	5A	88.65	86.76	4990.96
7	1478.31	-	506.86	7A	798.35	-	18.35
S	591.34	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

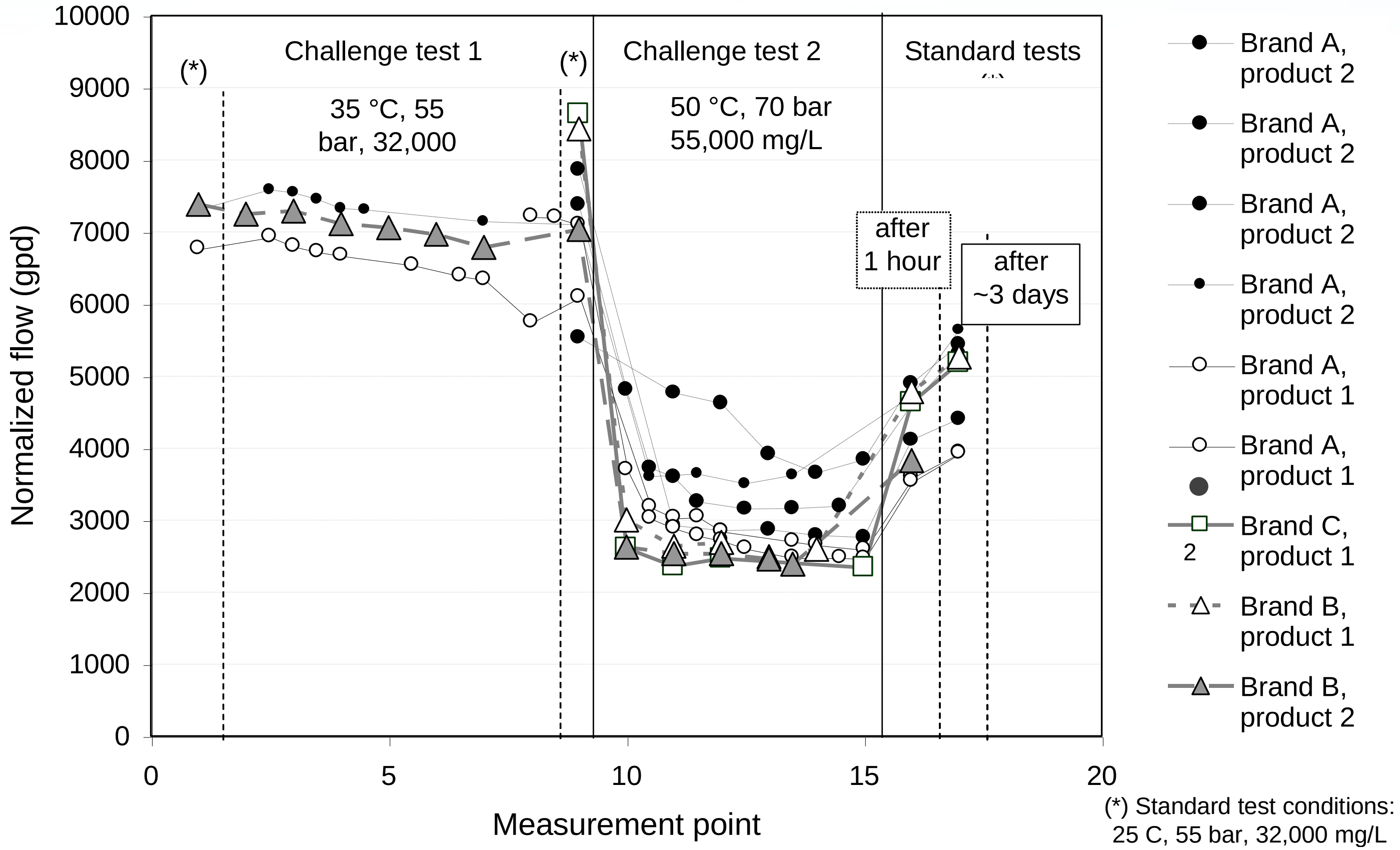
- RO operation at elevated temperatures (35ºC and above) causes an irreversible flow loss.
- Flow loss becomes apparent if the system is later operated at lower temperatures (20-35ºC).
- This is a phenomenon common to all thin film composite RO membranes operated under similar conditions.

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

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

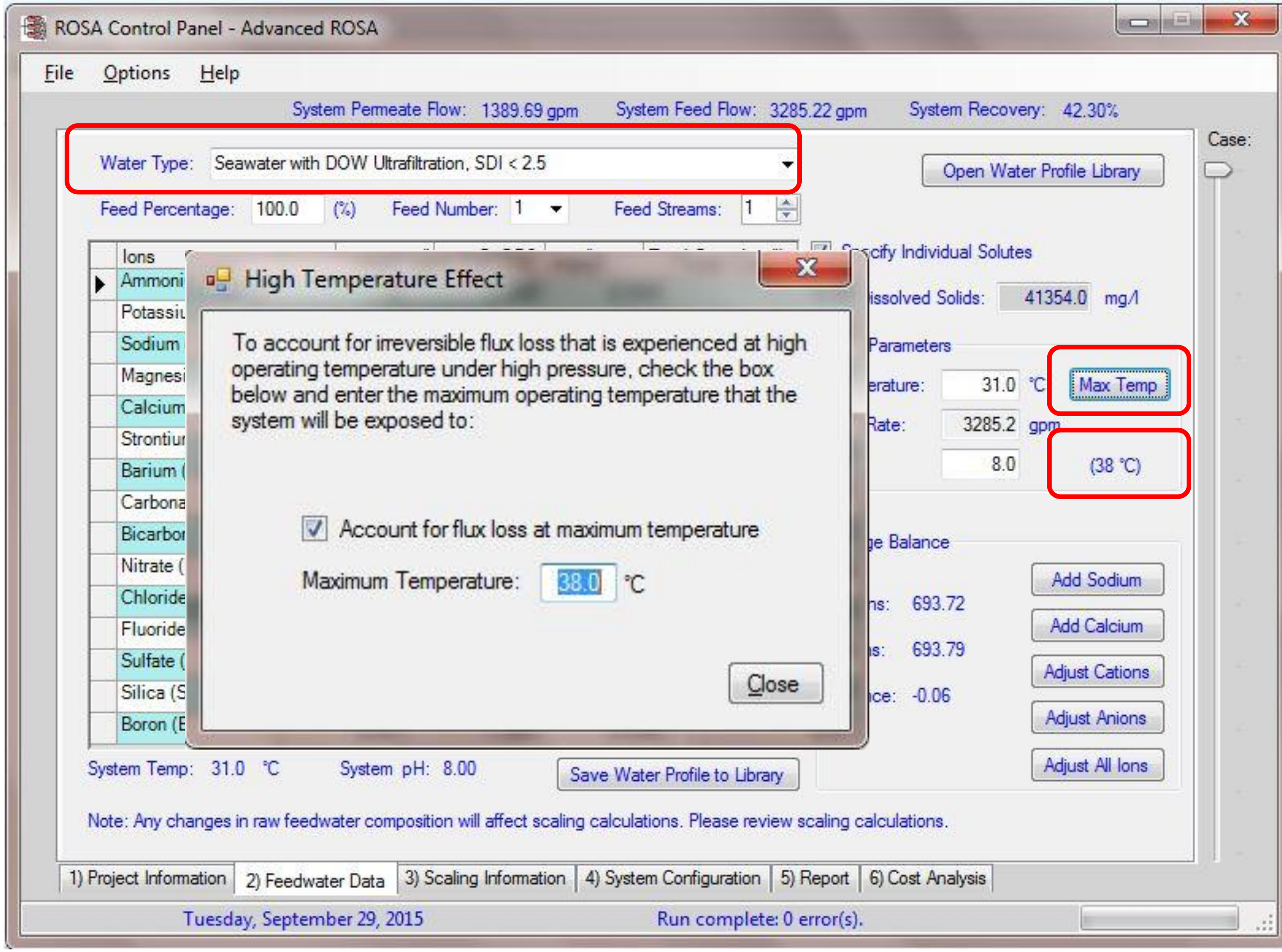


High Temp. Tests with SWRO elements

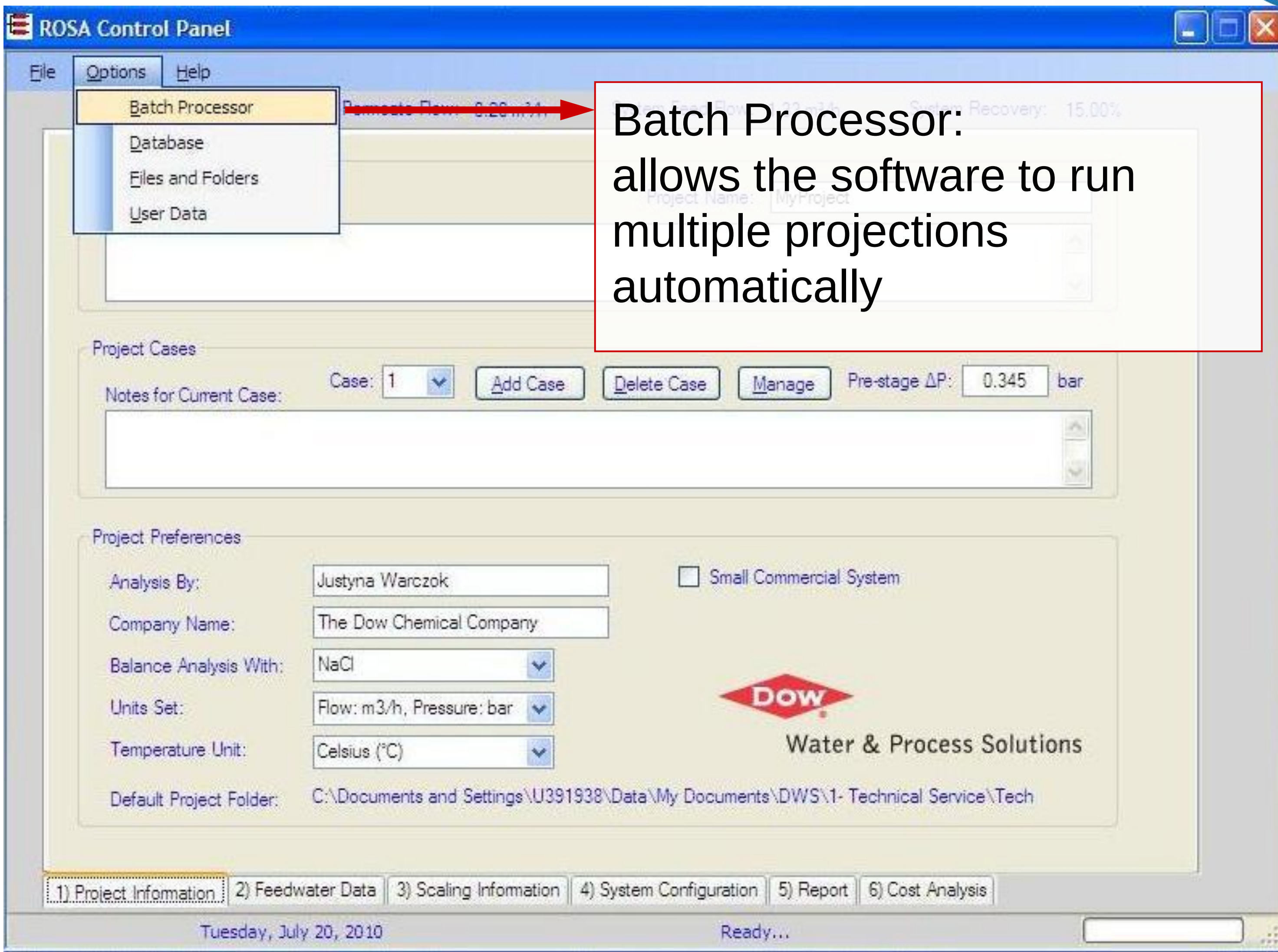


The hysteresis effect is inherent for all polyamide spiral wound RO modules.

ROSA – Temperature History Effect



ROSA – Control Panel: Options



Batch Processor:
allows the software to run multiple projections automatically

Batch Processor

Input Variables

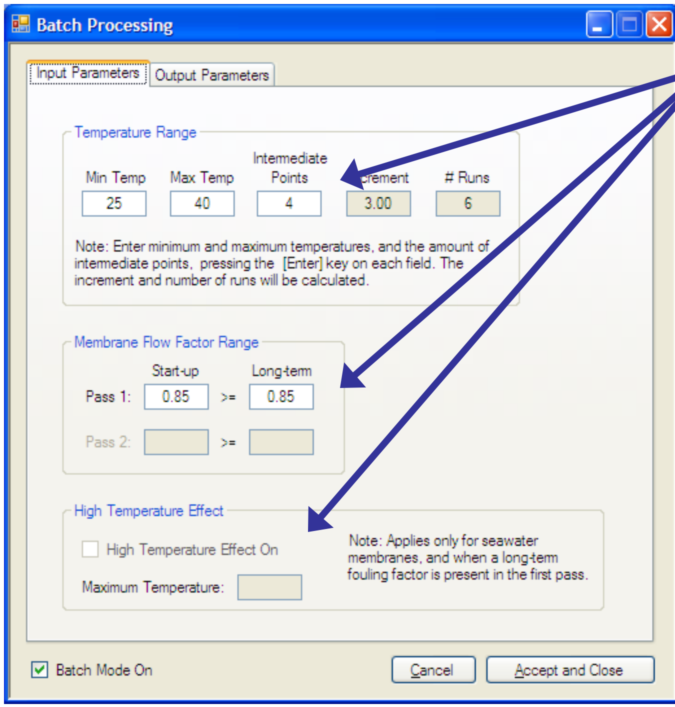
- Flow Factor: Start-up and Long term
- Temperature: Maximum & Minimum and desired number of intermediate points
- Option to activate the "High Temperature Effect"

Output

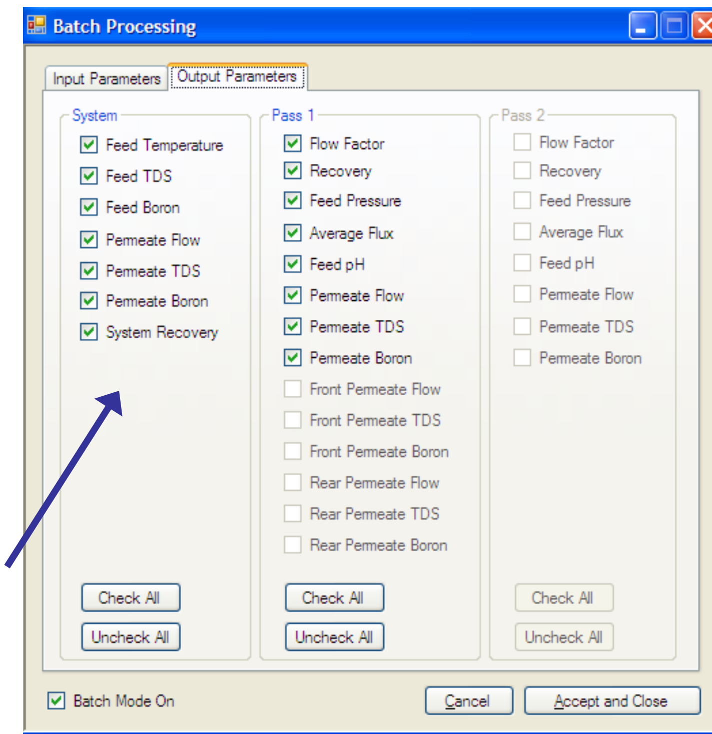
- ROSA will generate projections for each temperature at each Flow Factor indicated
- Projections can be stored in the same folder as the ROSA file
- A summary excel file can be generated as well. The parameters to be included in this summary are selected by the user

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, nº
Minimum	Maximum	Start up	Long term	3
10ºC	30ºC	1	0.75 – 0.65	

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

Output

The following projections will be generated

	10ºC	15ºC	20ºC	25ºC	30ºC
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

Batch Output

	FeedTemp	P1FF	FeedTDS	FeedBoron	SysPermFlow	SysPermTDS	SysPermB	SysRec	F
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	

Save as Excel File | Print | Close

Batch Processor – Output 2

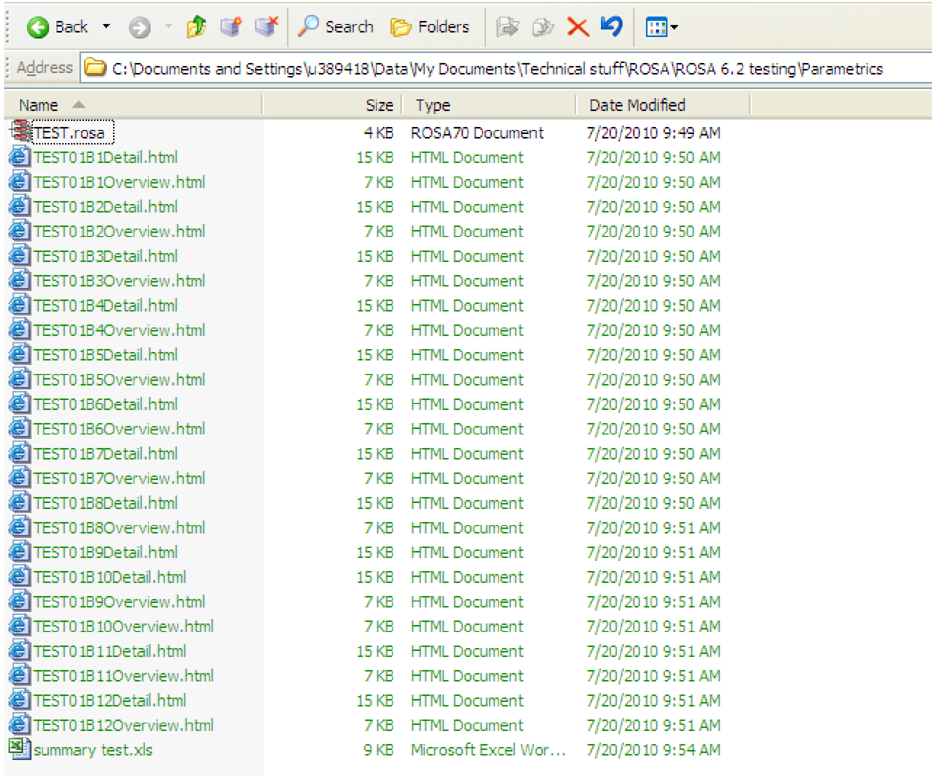
As a result, the user will get all the projections and the summary excel file

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 →



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Address: C:\Documents and Settings\u389418\Data\My Documents\Technical stuff\ROSA\ROSA 6.2 testing\Parametrics

Name	Size	Type	Date Modified
TEST.rosa	4 KB	ROSA70 Document	7/20/2010 9:49 AM
TEST01B1Detail.html	15 KB	HTML Document	7/20/2010 9:50 AM
TEST01B1Overview.html	7 KB	HTML Document	7/20/2010 9:50 AM
TEST01B2Detail.html	15 KB	HTML Document	7/20/2010 9:50 AM
TEST01B2Overview.html	7 KB	HTML Document	7/20/2010 9:50 AM
TEST01B3Detail.html	15 KB	HTML Document	7/20/2010 9:50 AM
TEST01B3Overview.html	7 KB	HTML Document	7/20/2010 9:50 AM
TEST01B4Detail.html	15 KB	HTML Document	7/20/2010 9:50 AM
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TEST01B10Detail.html	15 KB	HTML Document	7/20/2010 9:51 AM
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TEST01B12Detail.html	15 KB	HTML Document	7/20/2010 9:51 AM
TEST01B12Overview.html	7 KB	HTML Document	7/20/2010 9:51 AM
summary test.xls	9 KB	Microsoft Excel Wor...	7/20/2010 9:54 AM

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: 1.44m³/h)
WARNING: Maximum element recovery has been exceeded. Please change your system design to reduce the element recoveries. (Product: LE-400, Limit: 19.00%)

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

Solubility Warnings

Langelier Saturation Index > 0
Stiff & Davis Stability Index > 0
$BaSO_4$ (% Saturation) > 100%
Antiscalants may be required. Consult your antis ... .

Stage Details

Stage 1	Element	Recovery	Perm Flow (m³/h)	Perm TDS (mg/l)	Feed Flow (m³/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	1.16	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 (m³/h)**	**Perm TDS (mg/l)**	**Feed Flow (m³/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 **permeate flow** exceeded	3, 5, 7, 10
The **concentrate flow** less than minimum	1, 5, 4 together with 6
The **feed flow** greater than maximum	2 unless the feed flow is fixed, 3
Maximum **feed pressure** exceeded	1, 3, 8
Temperature is above acceptable value	9
Max. element **recovery** exceeded: • If the problem is encountered in front elements • If the problem is encountered in rear elements	 1, 5, 6, 10 1, 5, 6

Solutions Guide

1 Decrease system recovery

2 Increase system recovery

3 Reduce average system flux (add membranes, PV)

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.)

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

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

8 Install lower energy membranes or ISD with lower energy membranes

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

10 Combine two element types: lower energy elements in rear positions (ISD configuration)

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

Warnings and typical solutions – For multi-stage systems

WATER ACADEMY

Design warning	Solutions
Max. element **permeate flow** exceeded	3, (5), 6, 10, 13
The **concentrate flow** less than minimum	1, 4, (5), 6, 7, (10 and 11 only for the 1st stage)
The **feed flow** greater than maximum in any of the stages	2, 3
Maximum **feed pressure** exceeded	1, 3, 9
Temperature is above acceptable value	12
Max. element **recovery** exceeded: • If the problem is encountered in front elements (front stage/s) • If the problem is encountered in rear elements (rear stage/s)	 1, (5), 6, 7, 10, 13 1, (5), 7

Solutions Guide

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.)
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

*APF – Average Permeate Flux
PV=Pressure Vessel

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FILMTEC Membranes - e-mail pdf version of projection
FILMTEC Membranes - pH Adjustment in the Second Pass in **ROSA**
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