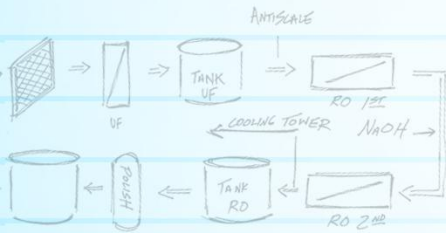
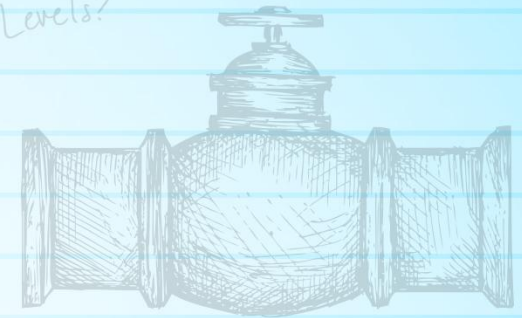


Expected Conductivity Levels?



Deaerating
pH Break vs. Con
Break - Cycle

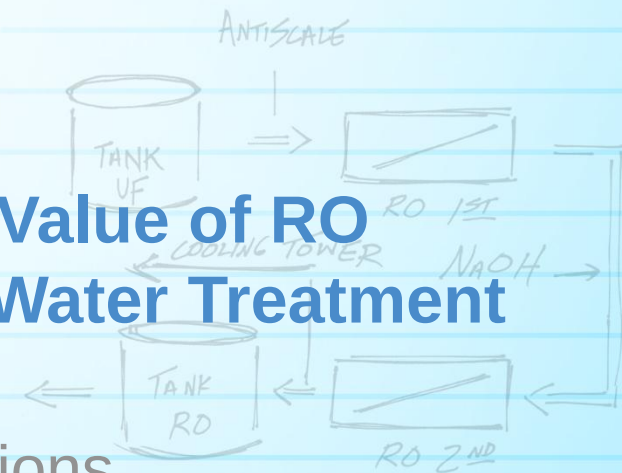


What are the
Water Quality
Guidelines?

Lessons Learned: Capturing the Value of RO Membrane Innovation in Boiler Feed Water Treatment

Steven Coker

Dow Water & Process Solutions



Topics



- Overview of Industrial Water Use
- Innovation of Brackish Water RO Technology
- Review of Case Histories
- Review of Economic Evaluation Tools

Industrial Water Usage

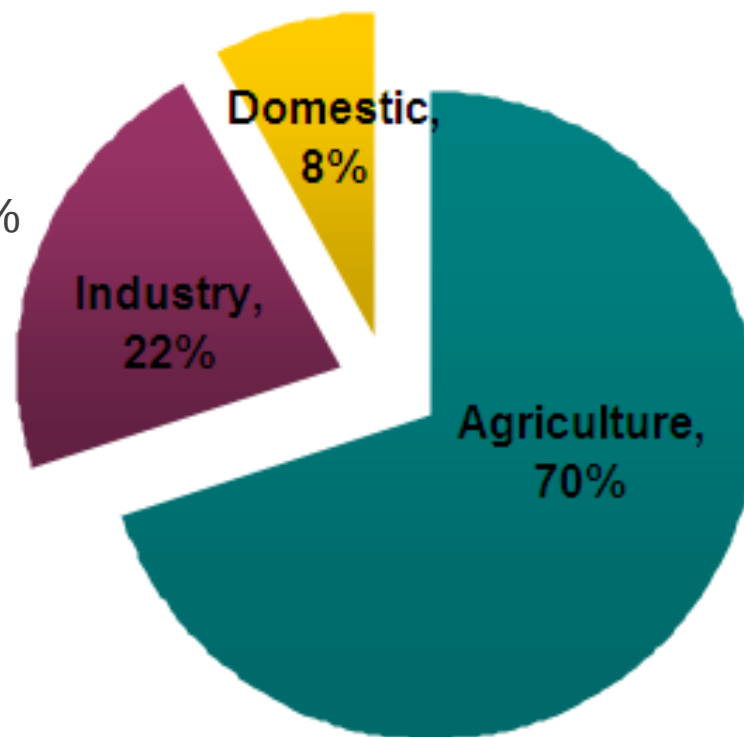


**Total global water usage
~ 655×10^{12} gallons / yr**

In US
45-50%

WHERE IS WATER USED?

- Cleaning, heating and cooling
- Generating steam
- Raw materials
- Solvent
- Aqueous based products
(e.g. beverage industry, coatings, etc.)
- Transporting dissolved substances/particulate

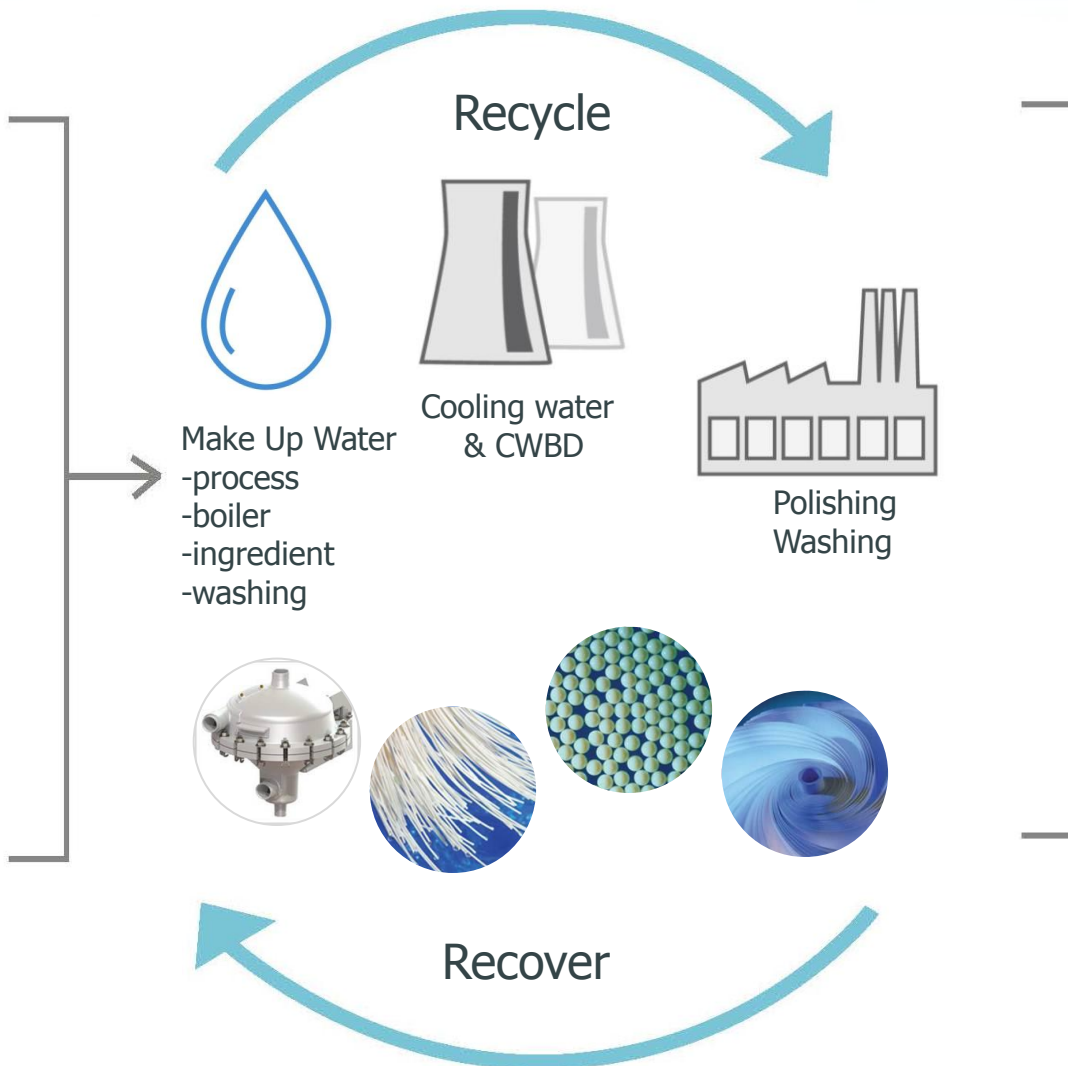


Source: Credit Suisse June 2007, UNESCO 2010

The Industrial RO Water Map



Water Source



Discharge cleanup



Municipal WWTP



Receiving body

RO Needs & Challenges in Industrial Applications



NEEDS

- Right water quality
- Right water quantity
- Predictable performance



- Operational reliability
- Constant performance
- Long RO element lifetime



CHALLENGES

- Operational issues
- Fouling, scaling, oxidation
- Changing environmental conditions
- Cost (CAPEX & OPEX)

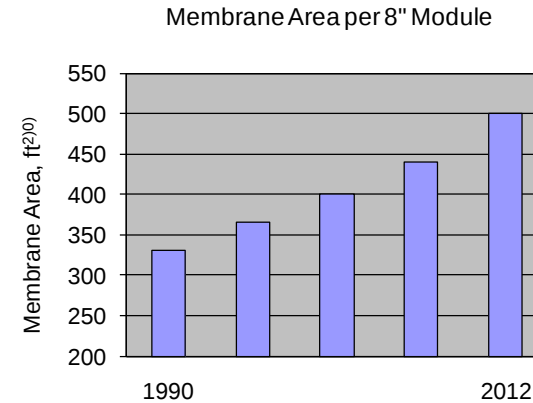
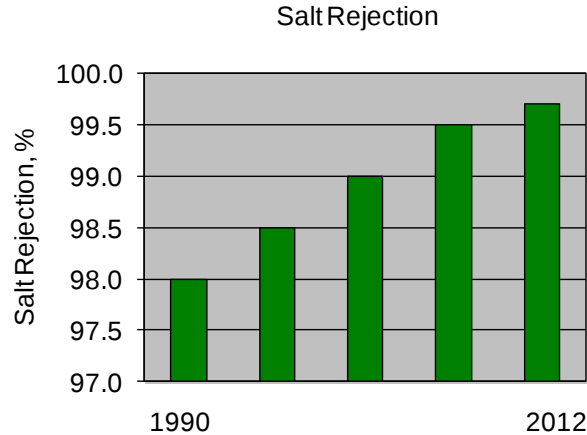


- Increased output requirements (quality and quantity)
- Lack of operational focus
- Heritage equipment

Two Decades of BWRO Innovation

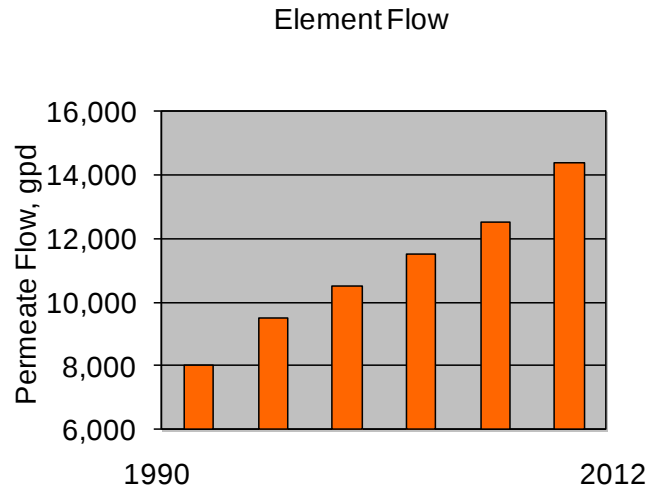


**Salt
passage
reduced
from 2%
to 0.3%**



**Membrane
area per
8-inch
element
increased
by > 50%**

**Element
flow
increased
by 80%**



**RO Technology is
Continuously Changing**

- 30% lower OPEX
- 50% lower CAPEX

Challenge & Solution #1

Midwest Cogeneration Station

Heritage Equipment

Operational Issues

High Operating Cost



Cogeneration: Demineralized Water for High Pressure Boilers



The Challenge

The original make-up water plant design uses river water to produce up to 245 gpm of boiler feed make-up for power generation and an additional 400 gpm of make-up water for steam generation for a paper mill.

Operational challenges:

- Variable water temp.: 35° to 80° F (2 to 27 °C)
- High energy costs during low temp. operation.

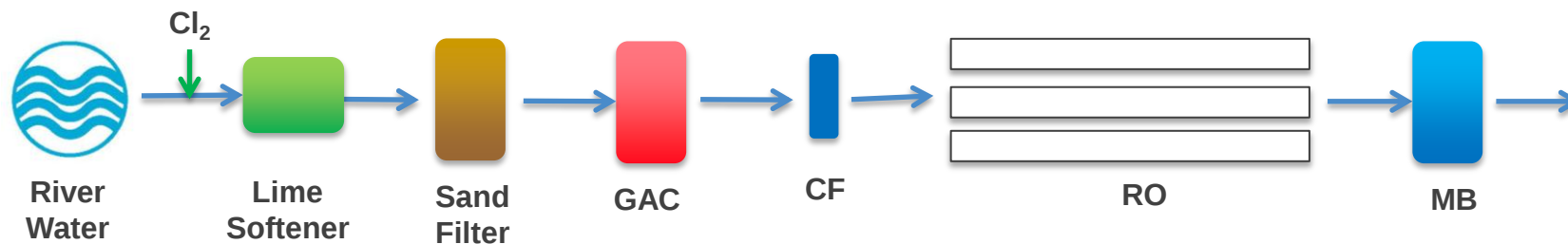
The Solution

The reverse osmosis (RO) membrane system was retrofitted with membrane elements manufactured with low energy membrane in an element configuration with increased membrane active area.

Cogeneration: Demineralized Water for High Pressure Boilers



Plant Layout



The Challenge

The original make-up water plant design uses river water to produce up to 245 gpm of boiler feed make-up for power generation and an additional 400 gpm of make-up water for steam generation for a paper mill. estuary water with very high inconsistency.

Operational challenges:

- Variable water temp: 35° - 80° F (2 - 27 °C)
- Production loss at low temp.
- High energy costs during low temp. operation.

The Solution

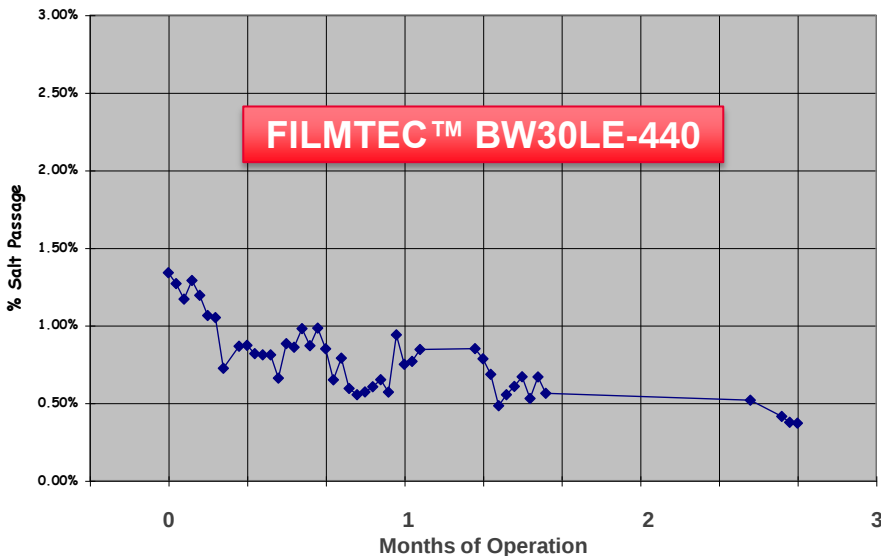
The reverse osmosis (RO) membrane system was retrofitted with first generation low energy membrane in an element configuration with increased membrane active area.

BW30-400 → BW30LE-440

Cogeneration: Demineralized Water for High Pressure Boilers



Salt Passage, (%)



The Result

After retrofit the plant could reach stable and predictable performance with tangible bottom line benefits:

- The feed pressure requirement was reduced by 60 psig (4 bar) or 20% when compared to other RO trains.
- Consistent permeate production rate across entire temperature range.
- The permeate TDS was equivalent or better than other trains.
- During the first 5 years of element life the energy savings from the use of low energy RO elements was \$486 per element.

Challenge & Solution #2

Midwest Cogeneration Plant - Cedar Rapids, IA

Heritage Equipment

Biofouling Risk

High Operating Cost

Membrane Upgrade Opportunity



Cogeneration Plant: Boiler Feed Water



The Challenge

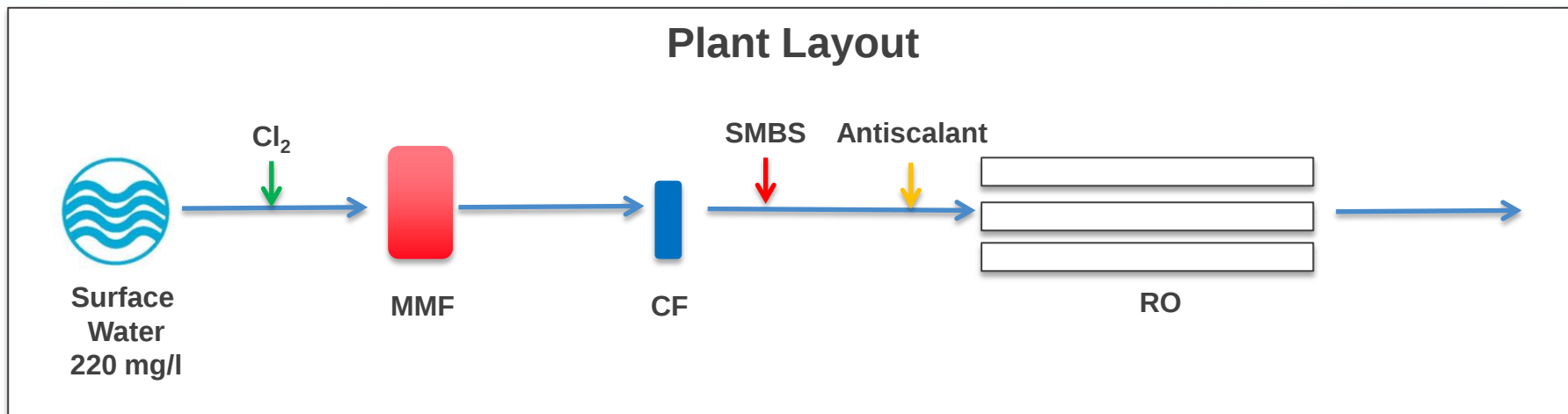
Fed from a surface water supply, the RO system with standard FILMTEC™ BW30-400 elements performed well but costs associated with fouling mitigation common with surface water plants resulted in elevated operating costs.

The Solution

A planned plant upgrade offered the opportunity to evaluate an improved membrane element with a thicker feed channel spacer. FILMTEC BW30-400/34*i* elements featuring a 34 mil feed channel spacer were installed to compare performance with a new set of standard FILMTEC BW30-400 elements with the standard 28 mil feed channel spacer installed in an adjacent train.



Cogeneration Plant: Boiler Feed Water

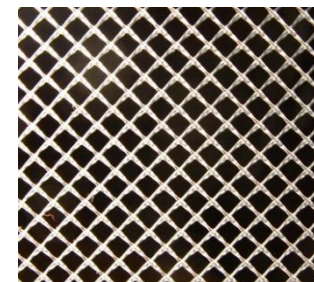
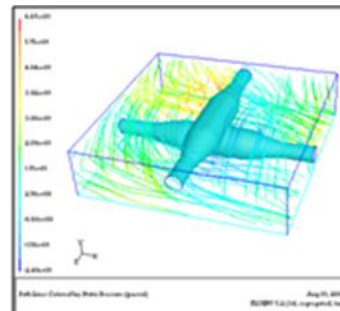
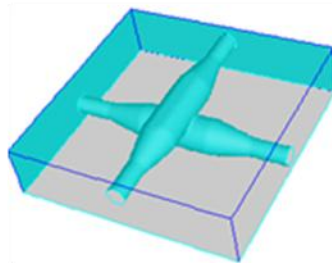


Element	Flow, gpd*	Rejection, %*	Area, ft ²	Spacer, mil
BW30-400	10,500	99.5	400	28
BW30-400/34 <i>i</i>	10,500	99.5	400	34

*Permeate flow and rejection based on the following standard conditions: 2,000 ppm NaCl, 225 psi, 77°F, pH 8, and 15% recovery.

RO Feed Spacer Concepts

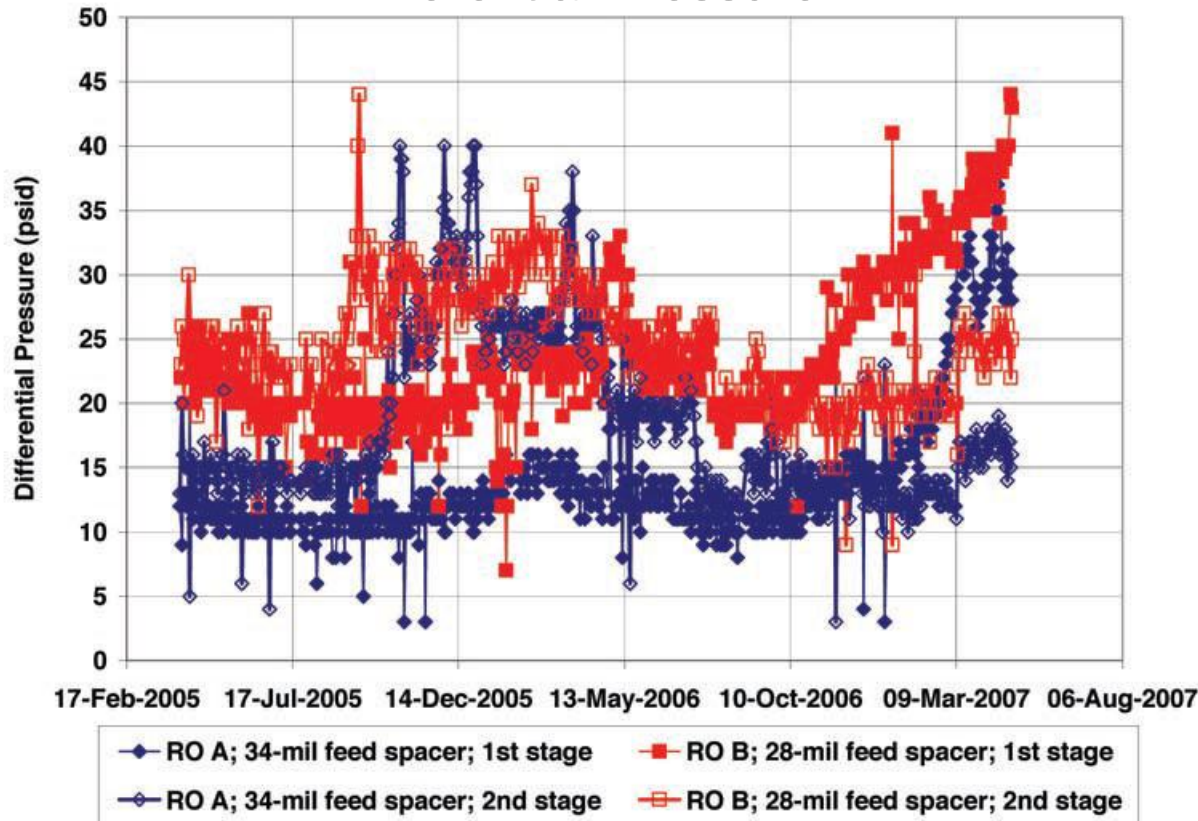
- Provides an area for feed flow through the RO element
- Increases turbulence at membrane surface to mitigate fouling and salt concentration polarization
- Thicker feed channel spacers have been shown to provide:
 - Reduced differential pressure
 - Increased fouling resistance
 - Enhanced cleaning efficiency



Cogeneration Plant: Boiler Feed Water



Differential Pressure



The Result

Elements with 34 mil feed spacer had:

- 40-70% lower pressure drop
- Less frequent cleanings
- Cost savings from lower feed pressure alone was >\$100/element over 3 year element life

Challenge & Solution #3

Blackhawk Power Station, Southern USA

High Operating Costs

Product Flow Decline in Winter

Poor Cleaning Results



Gas Fired Power Plant: Boiler Feed Water Make Up



The Challenge

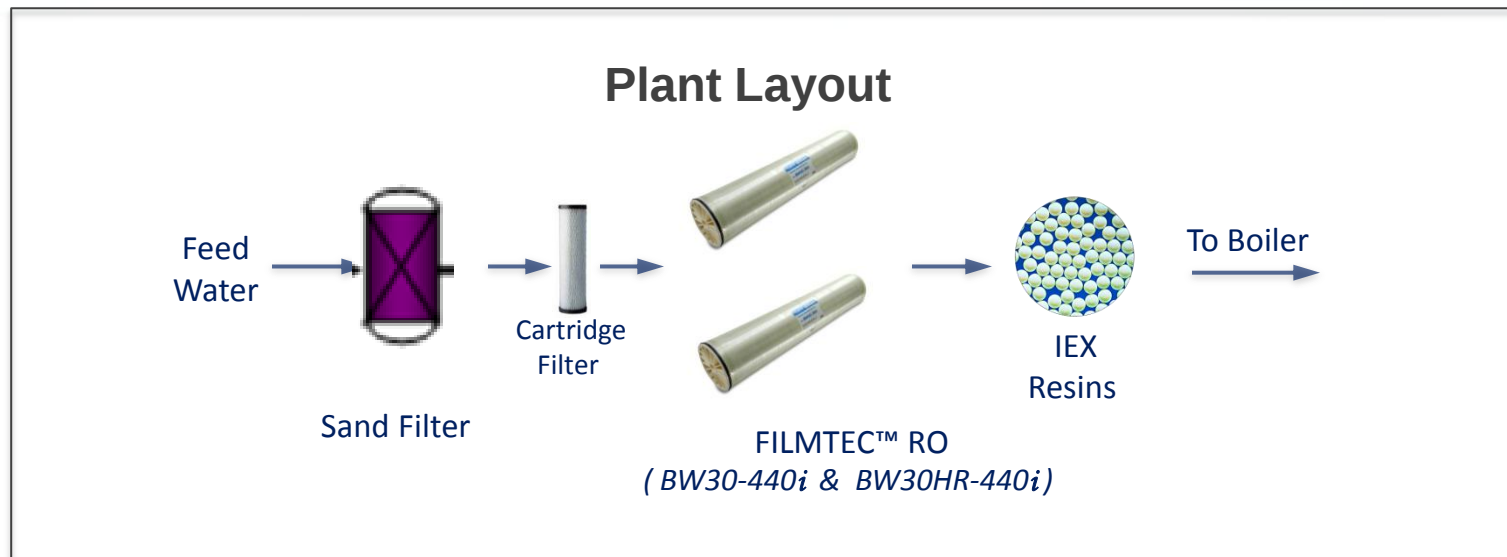
Plant looking to improve water productivity during cold season (HP pump limitation), increase system robustness and reduce the operational costs.

Solution

The plant conducted side by side trial by replacing two RO trains with new elements:

- One with new membranes with improved rejection – BW30HR-440*i*
- One with new, standard membranes – BW30-440*i*

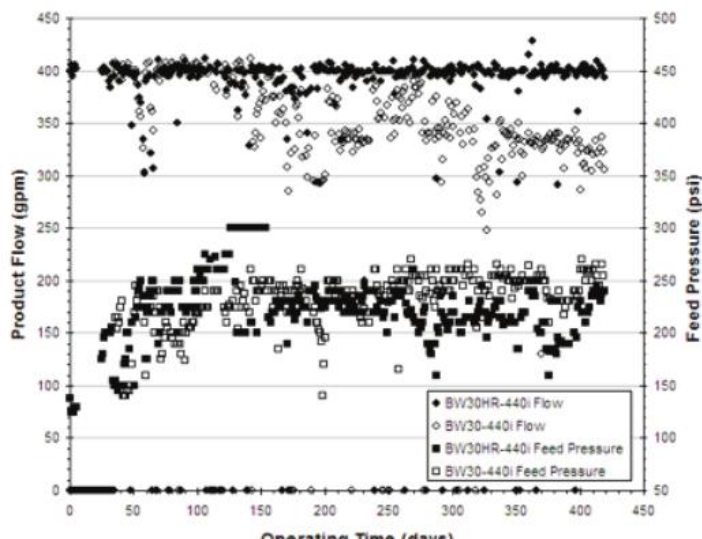
Gas Fired Power Plant: Boiler Feed Water Make Up



Element	Flow, gpd*	NaCl Rejection, %*	SiO ₂ Rejection, %*
BW30-440i	11,500	99.5	99.7
BW30HR-440i	12,650	99.7	99.9

*Permeate flow and rejection based on the following standard conditions: 2,000 ppm NaCl, 225 psi, 77°F, pH 8, and 15% recovery.

Gas Fired Power Plant: Boiler Feed Water

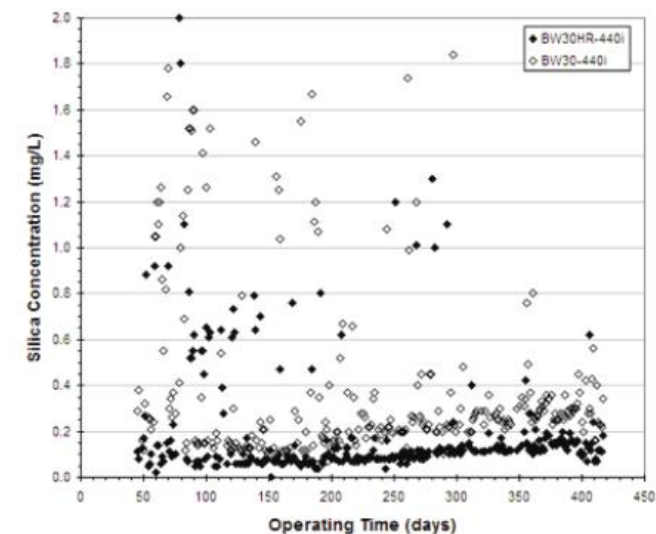


The Result

- Ionic load to MB 25-50% lower with high rejection membranes, reducing the regeneration costs proportionally.
- BW30HR-440i produced 21% more water at 10% lower energy than BW30-440i.

Additional Benefits

- Extends operating window so sufficient supply of make-up water can be produced in cold seasons
- Reduced ionic demand on mixed bed polisher, saving money on regeneration chemicals
- Reduced amount of silica to be removed by the mixed bed polisher, extending time between regeneration periods



Challenge & Solution #4

Managing OPEX and CAPEX in the Future



Upgrade RO Systems to Capture OPEX Savings



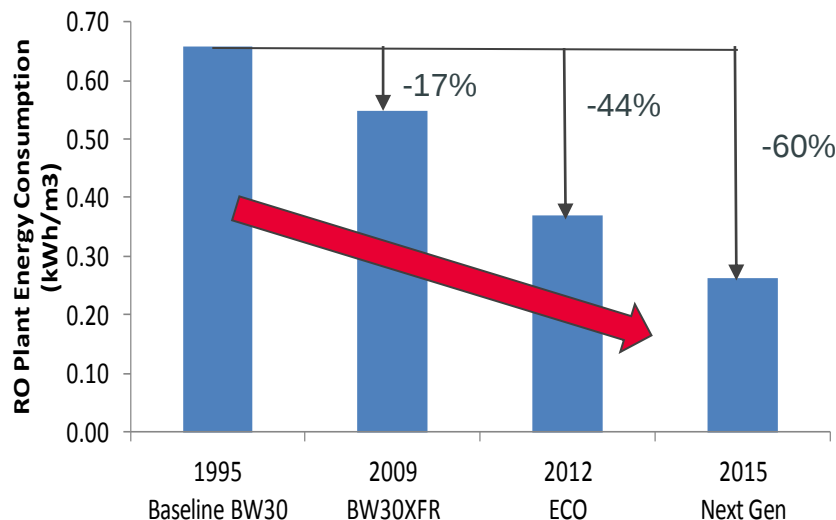
The Challenge

RO membranes last a long time, typically between 3-7 years. Replacement often done with the same element as originally installed, although significant development in RO elements has occurred during that time.

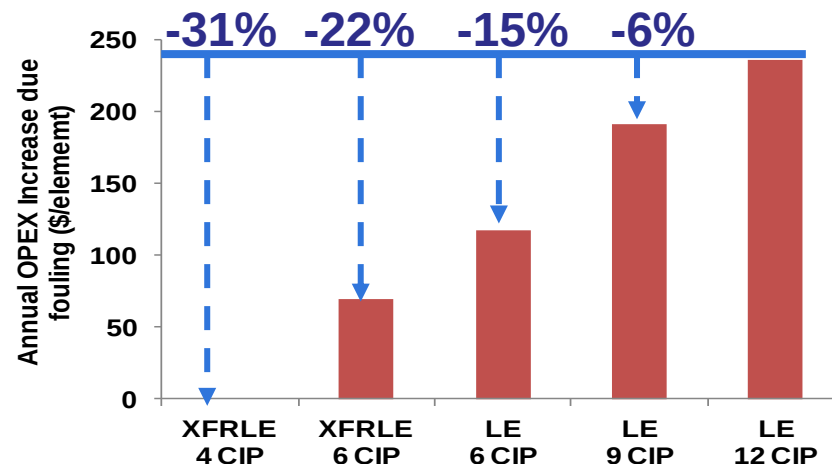
The Solution

Before replacing your membranes with the same product, evaluate the benefits that could be obtained from newer membrane technologies.

ENERGY REDUCTION



FOULING REDUCTION

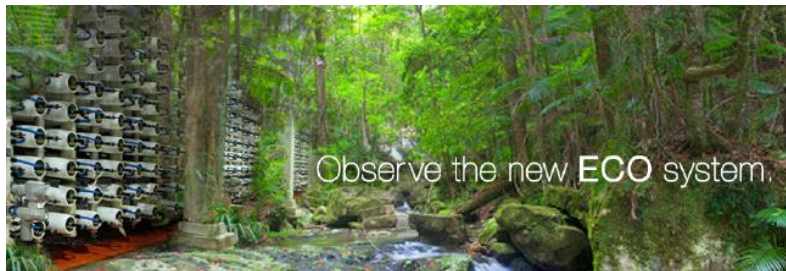


FILMTEC™ ECO Membranes



New membrane chemistry that **enables higher rejection at low energy** as well as delivering fouling resistant characteristics

Supported by innovation in feed spacer technology reducing the system size and further improving the system energy efficiency



- ECO Membranes will increase sustainability efforts for an **ECO**logical solution
- ECO Membranes will provide opportunity to save energy and chemical costs for an **ECO**nomical solution



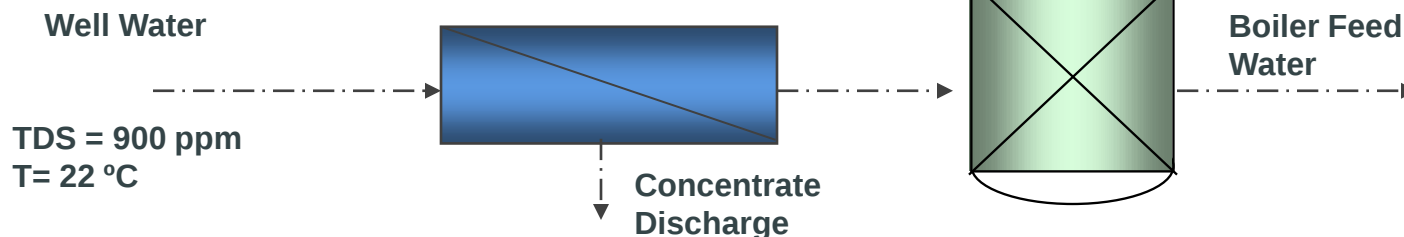
FILMTEC™ ECO Membranes

Value of Chemical & Energy Saving



1st Pass RO Mixed Bed

BW30-400 vs. ECO-400i



RO Energy Saving

1st Pass (Input from ROSA)

	Current Elements			ECO			ECO Improvement		
	Feed P (psi)	Energy (kWh/kgal)	TDS mg/l	Feed P (psi)	Energy (kWh/kgal)	TDS mg/l	Feed P	Energy	TDS
Start Up	165.24	2	8.87	100.18	1.21	7.63	-39%	-40%	-14%
Long Term	187.84	2.27	8.76	111.97	1.35	7.5	-40%	-41%	-14%

	Current Elements	ECO	ECO Improvement
Time between Regenerations (hr)	72	80	Number of Regenerations -10%
# of Regenerations per year	110	99	

RO Energy & MB Chemical Savings

Total ECO Savings

Savings Over Element Lifetime

\$8,086 / Year	\$40,430 / 5 Years
\$225 / RO Element / Year	\$1,125 / RO Element / 5 Years

ECO Energy Savings

\$6,067 / Year

\$169 / RO Element / Year

ECO Regenerants Savings

\$2,019 / Year

\$56 / RO Element / Year

Summary



- As reverse osmosis has matured as a technology there are operational challenges which have arisen from heritage equipment, pretreatment issues, source water quality, and increasing quantity and quality requirements.
- These challenges have opened the door for solution seekers to take advantage of innovations in membrane chemistry and element module design which address these challenges.
- The latest generation of RO membrane products delivers savings in both CAPEX and OPEX and provides sustainability for the future.

Questions?

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

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