Connecting Application Requirements and Fundamental Science: Delivering New Water Component Technologies

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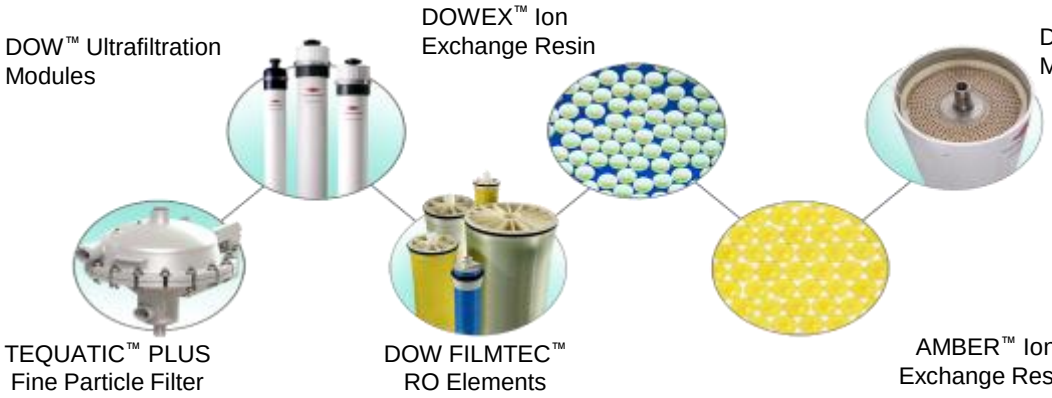
Agenda

- Dow Introduction
- Dow Water & Process Solutions Overview
- Technology Screening
- Reverse Osmosis
- Ultrafiltration
- Macrofiltration

Dow Technologies and Market Solutions

The most complete portfolio in the industry today and a global presence second to none with #1 positions in Reverse Osmosis and Ion Exchange

Product Platforms



Markets Served


CATALYSIS & CHEMICAL PROCESSING


FOOD & BEVERAGE


POWER GENERATION


MINING & HYDROMETALLURGY


INDUSTRIAL WATER


PHARMACEUTICAL


MUNICIPAL & DESALINATION


RESIDENTIAL & COMMERICIAL


WASTEWATER & REUSE

Enabling Components

Primary Loop (Roughing Stage)

2B3T System (UPCORE* System)

Optional

Single Pass RO + Working Mixed Bed

Double Pass RO

Single Pass RO + CDI or EDI

RO

IX

EDI

UF

Pre-treatment System

Storage Tank

Multi Media Filter or UF

Storage Tank

Raw Water

Optional

Polishing Mixed Bed

Storage Tank

Secondary Loop (Polishing Stage)

UV

Final Polisher

UF

Reclaim (Recovery) System

Storage Tank

Point of Use

Discharge

Technology Screening

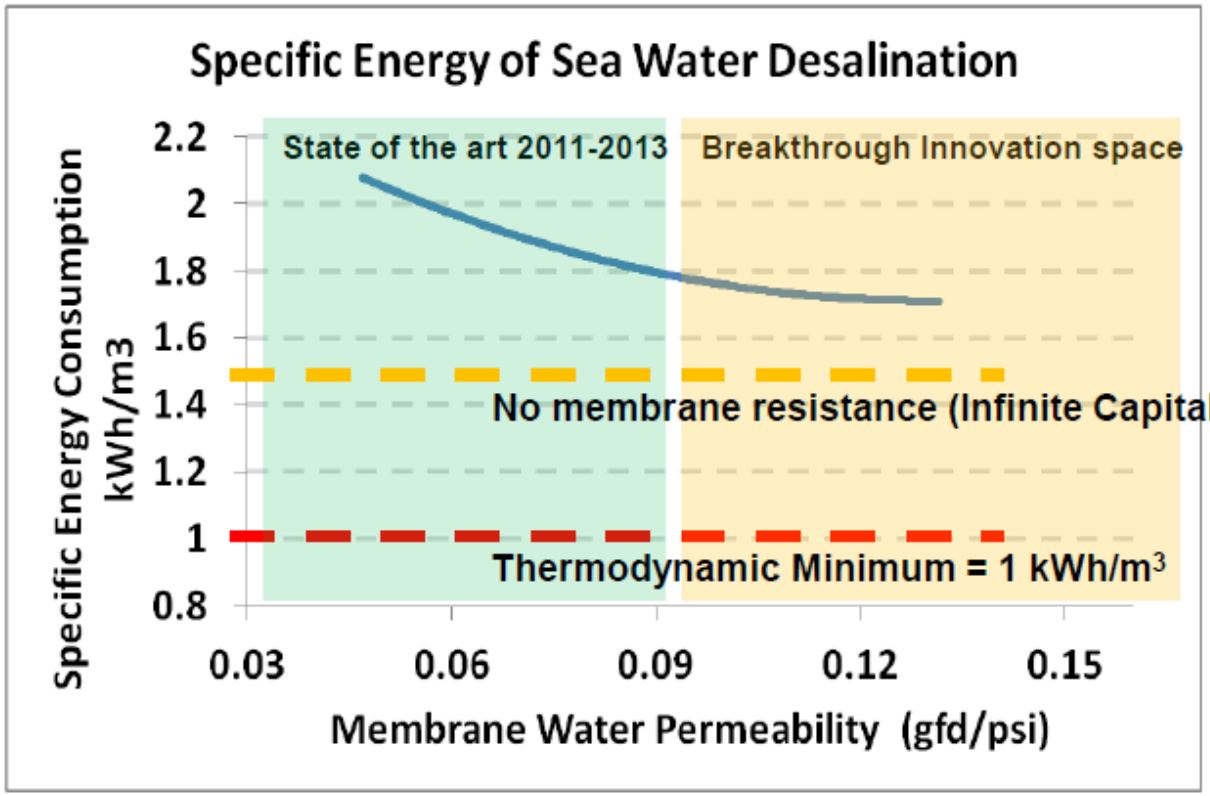
- Is it real?
  - Mass and Energy balance
  - Techno-Economic Analysis
  - Solid water/wastewater market drivers
- Does it fit?
  - Component, Equipment, System or Service model?
- Can it be more successful with a Dow relationship?
  - Augmented by R&D strength, global reach, partnership relations?
  - 1+1>2

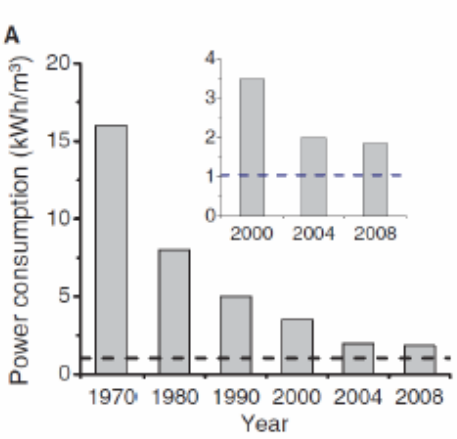
RO and UF: Energy and Membranes

- Visible discussion because of OpEx considerations:
  - RO discussion has been largely around energy recovery devices and the membrane permeance
    - A high water permeability, “A” is desired
    - A low salt permeability, “B” is also desired
  - UF is concerned about operational flux
    - Fouling and subsequent water recovery issues

Specific Energy in Sea Water Desalination is Approaching the Practical Thermodynamic Minimum

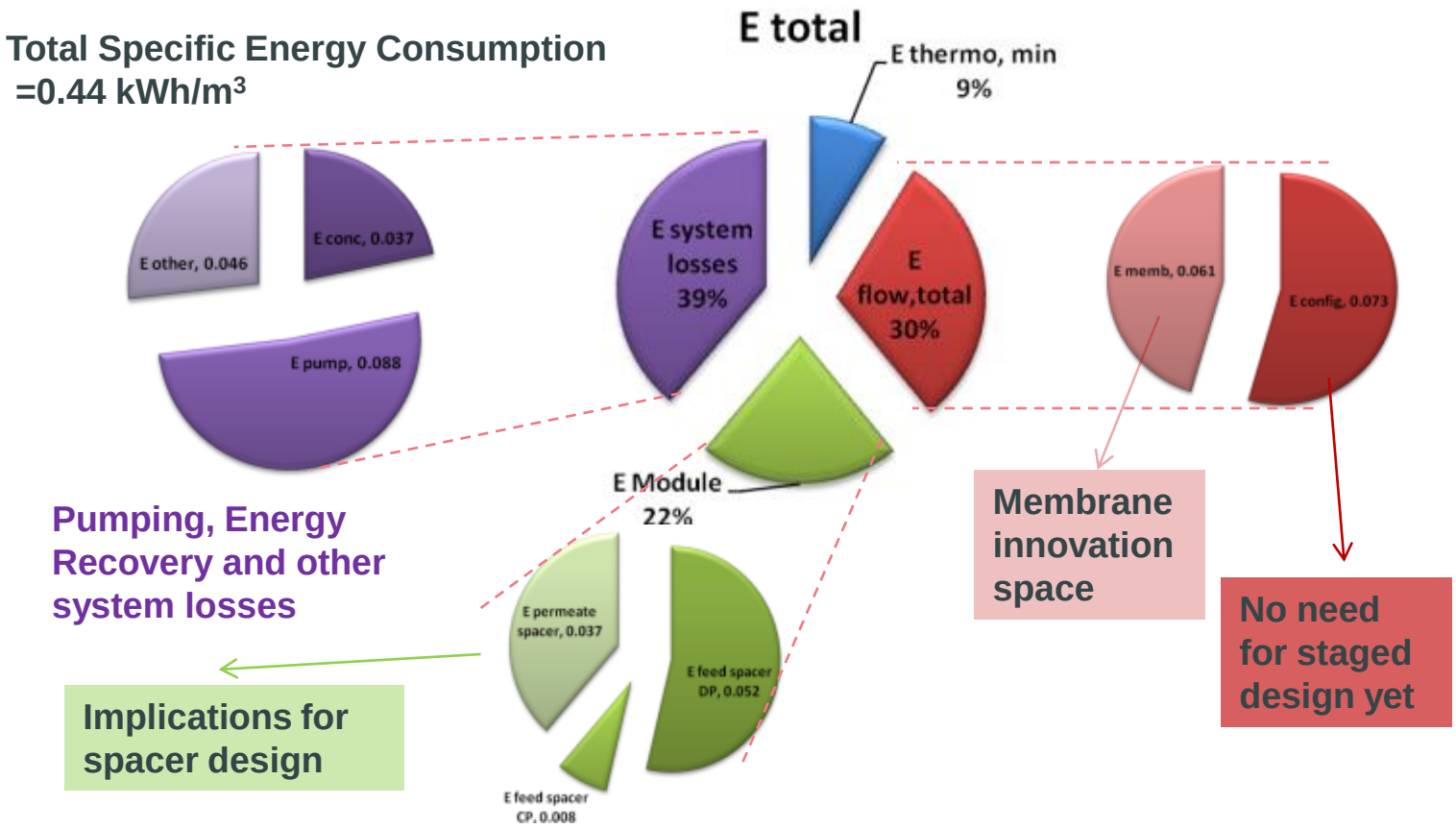
Sea water desalination energy efficiency is asymptoting





[1]*Elimelech et al., Science 333, Aug 2011*

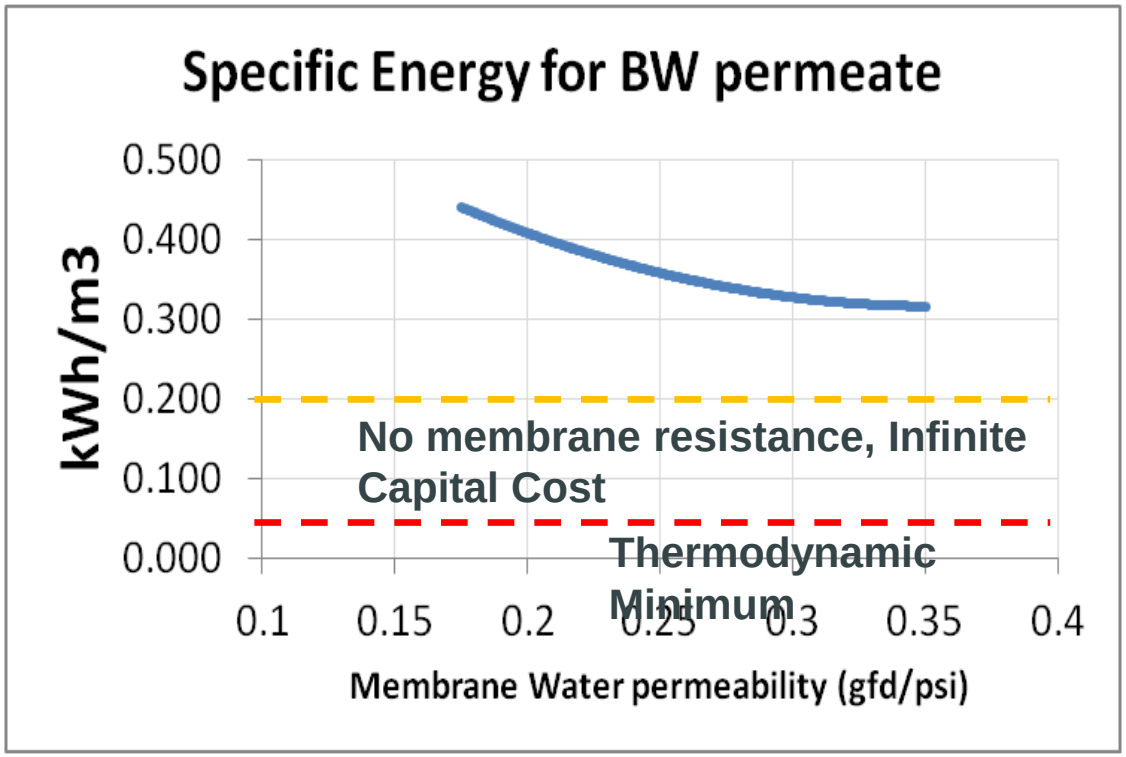
Brackish Water Desalination Energy Breakdown



- Energy conversion losses ~ 40%
- Pressure losses in the module constitute 20% of the total energy consumption
- Membrane innovation potential before capital cost ~15% of total current specific energy

Specific Energy Trends in Brackish Water Desalination

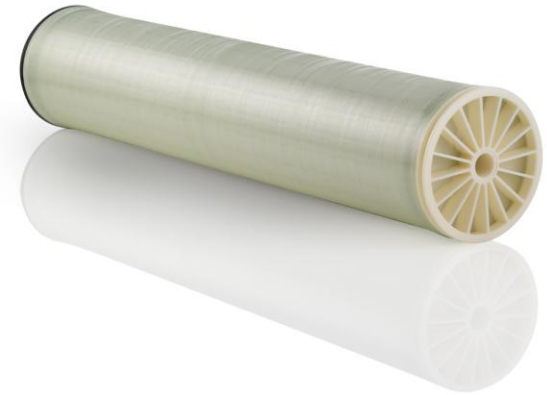
Substantial improvements in membrane now are leading to smaller returns in energy savings due to other contributing factors



Current and Future Status

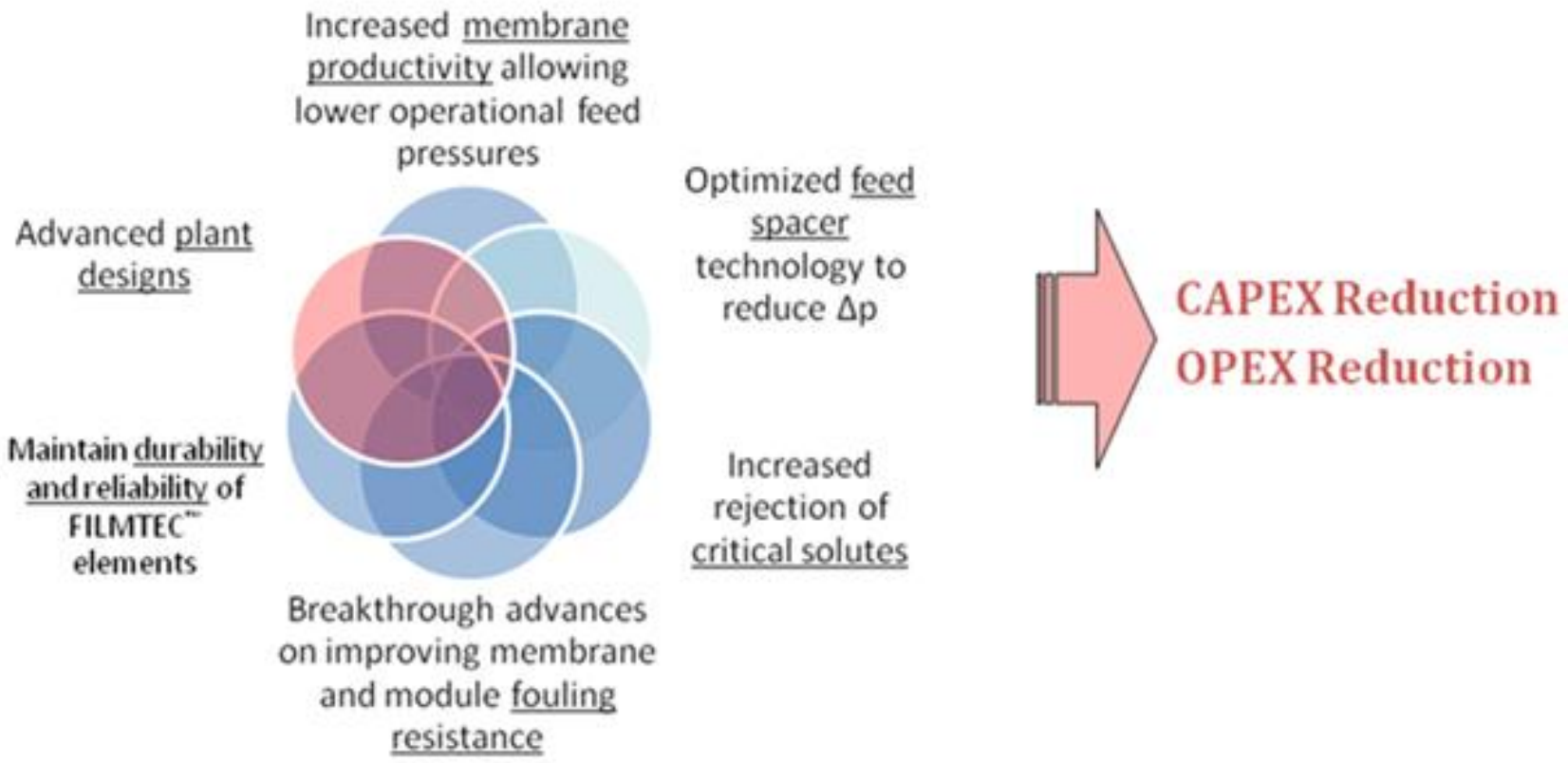
- Diminishing energy savings in desalination with membrane innovation alone
  - High permeability membranes alone will no longer give same returns in energy savings in reverse osmosis desalination as in the past
  - BW Desalination: System losses become a major portion of overall energy consumption
  - SW Desalination: Thermodynamic Minimum Energy for desalination accounts for more than half of the desalination energy
- Configurational energy (system design) and element design have elements that can enable further energy savings (at the cost of CAPEX)
- Research focuses on operational stability

Low Energy Brackish Water Membranes

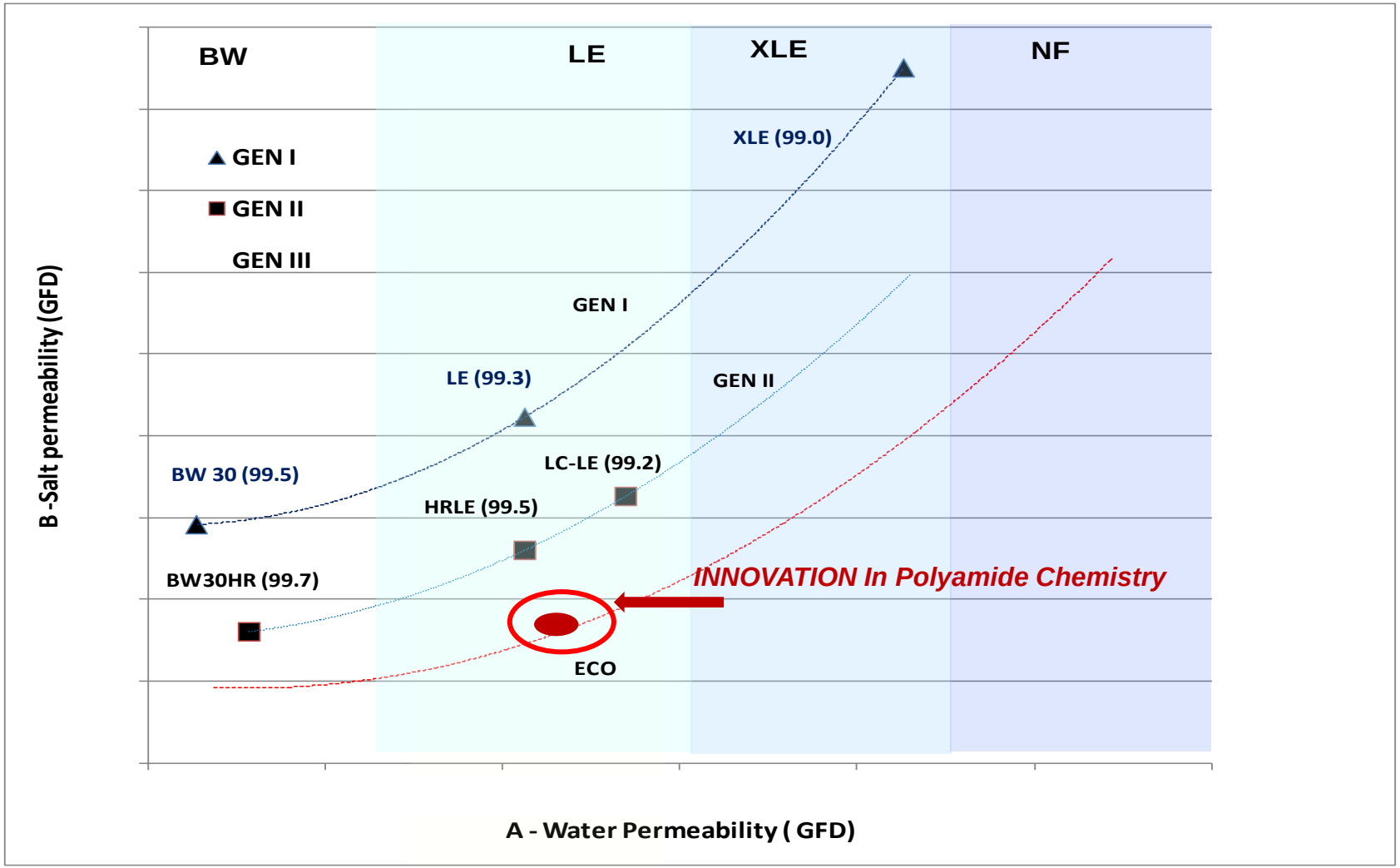


DW&PS Strategic Reduction Objective

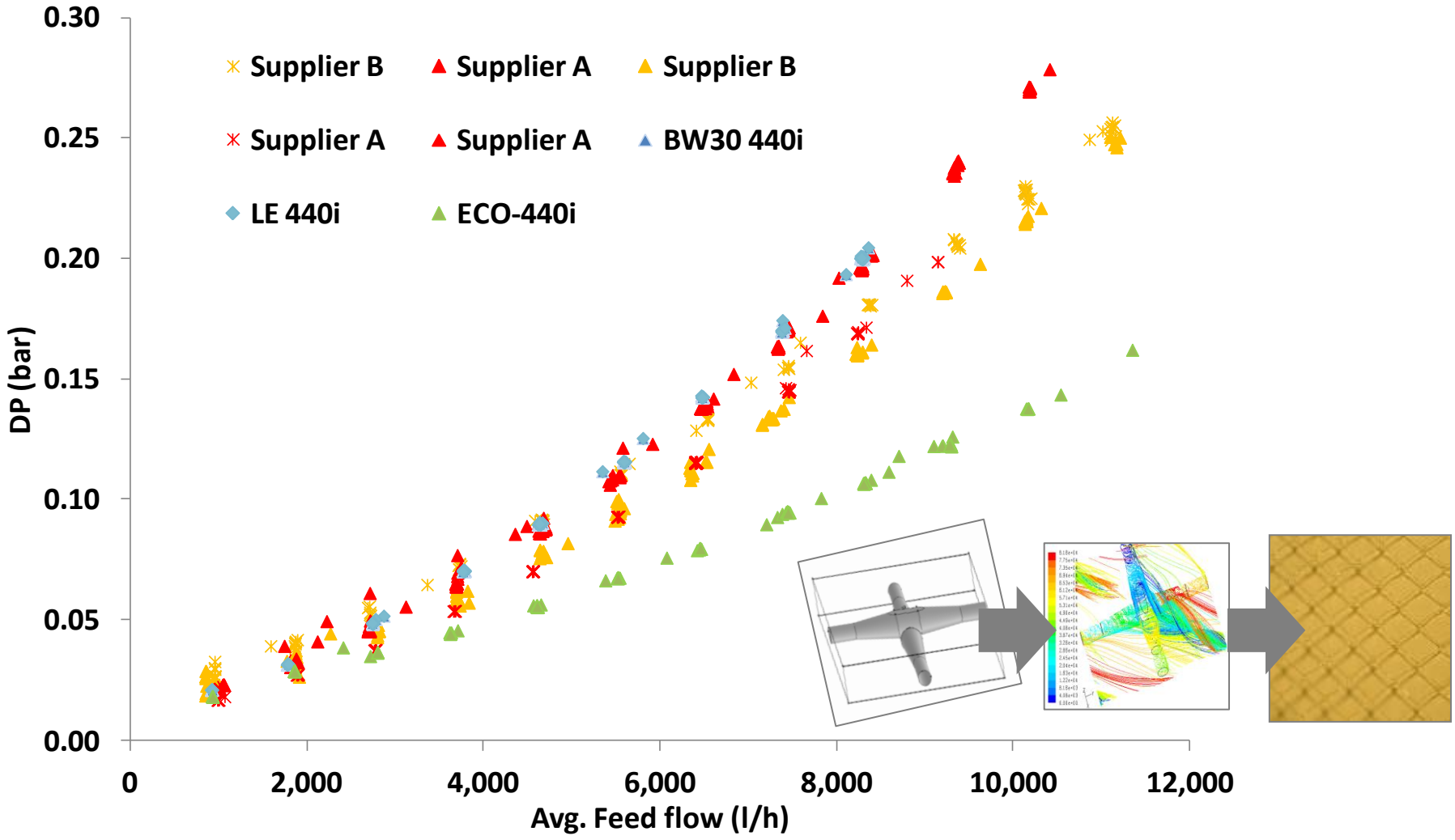
Reduce cost of water by 35%



DOW™ FILMTEC™ Membranes – Novel Low Energy Membranes



DOW™ FILMTEC Membranes – Novel Feed Spacer



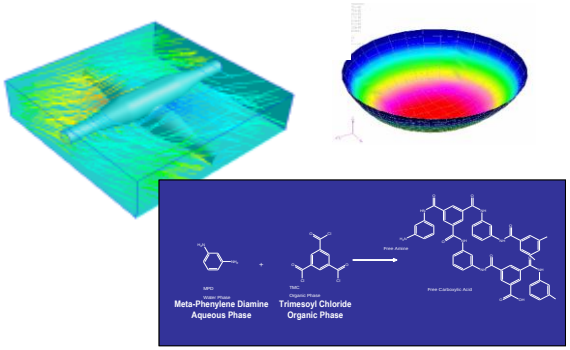
DOW™FILMTEC™ ECO Low Energy Brackish Water RO

- Delivers end-use customers the industry's highest rejection low energy BWRO membrane
  - Lower operating pressure by 30% while retaining permeate quality
  - Lower permeate TDS by 40% while maintaining feed pressure
- Target markets: Industrial & Power

Transformation With ECO, a new kind of plant emerges. One that runs on less energy and reduces environmental stress and strain. An element designed with an ecological conscience so powerful it transforms your plant into an entirely new ECO system. Lines blur between manufacturing plants and lush ecosystems. A phenomenon that causes naturalists to take note. And track ECO's effects accordingly.

Life Cycle: From Innovation to Product

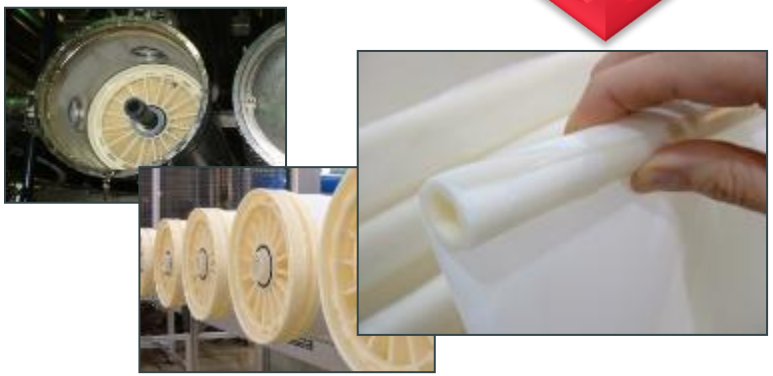
Modeling



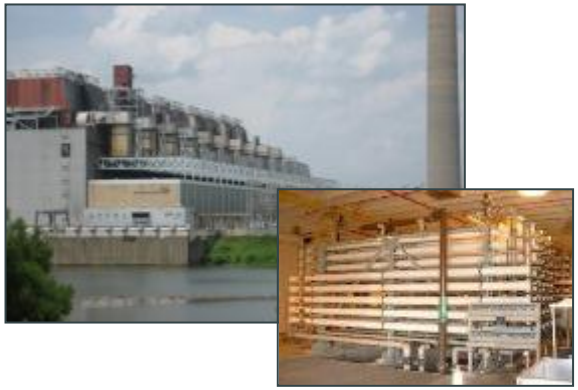
Piloting/Prototyping

Laboratory Evaluation

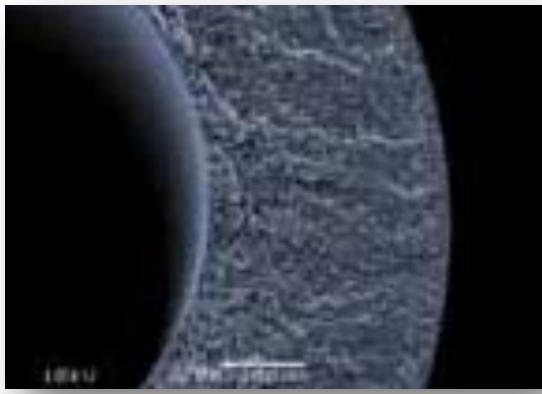
Fabrication and Testing



Field Trial Validation



High-Performance DOW™ Ultrafiltration



DOW IntegraPac™ Skids

Optimization of Ultrafiltration Membrane Cleaning Processes

Hypotheses:

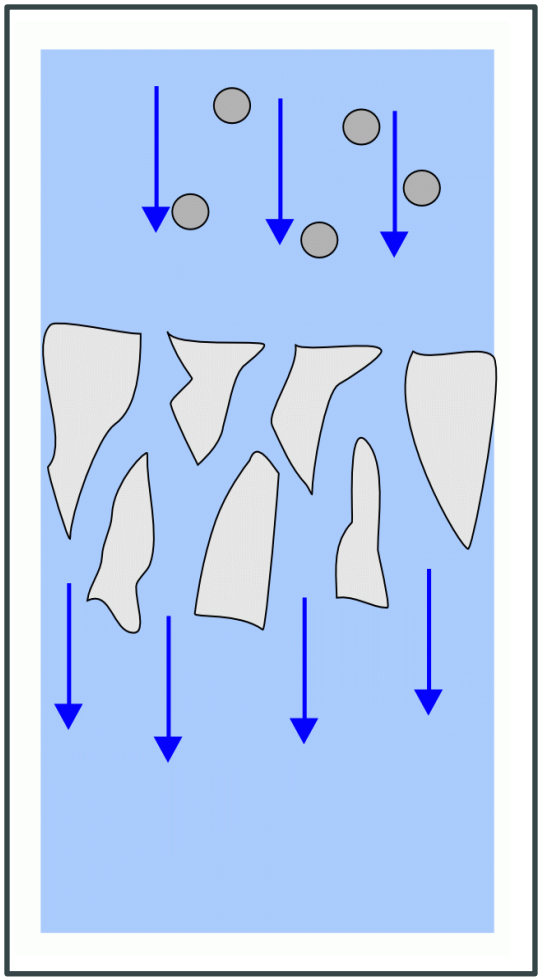
The efficiency of the ultrafiltration process can be increased by improving its cleaning steps performance in SW Desal

Gilabert-Oriol, G.; Moosa, N.; Garcia-Valls, R.; Busch, M. and Garcia-Molina, V.; *Optimizing seawater operating protcols for pressurized ultrafiltration based on advanced cleaning research, Desal. and Water Treatment, 51(2013) 384-396.*

Fouling

- Fouling in ultrafiltration is due mainly by particles blocking membrane pores and particles building a gel layer above the membrane which reduces filtration area

- Therefore, to keep filtration flux constant, more pressure from feed pump (TMP) is required

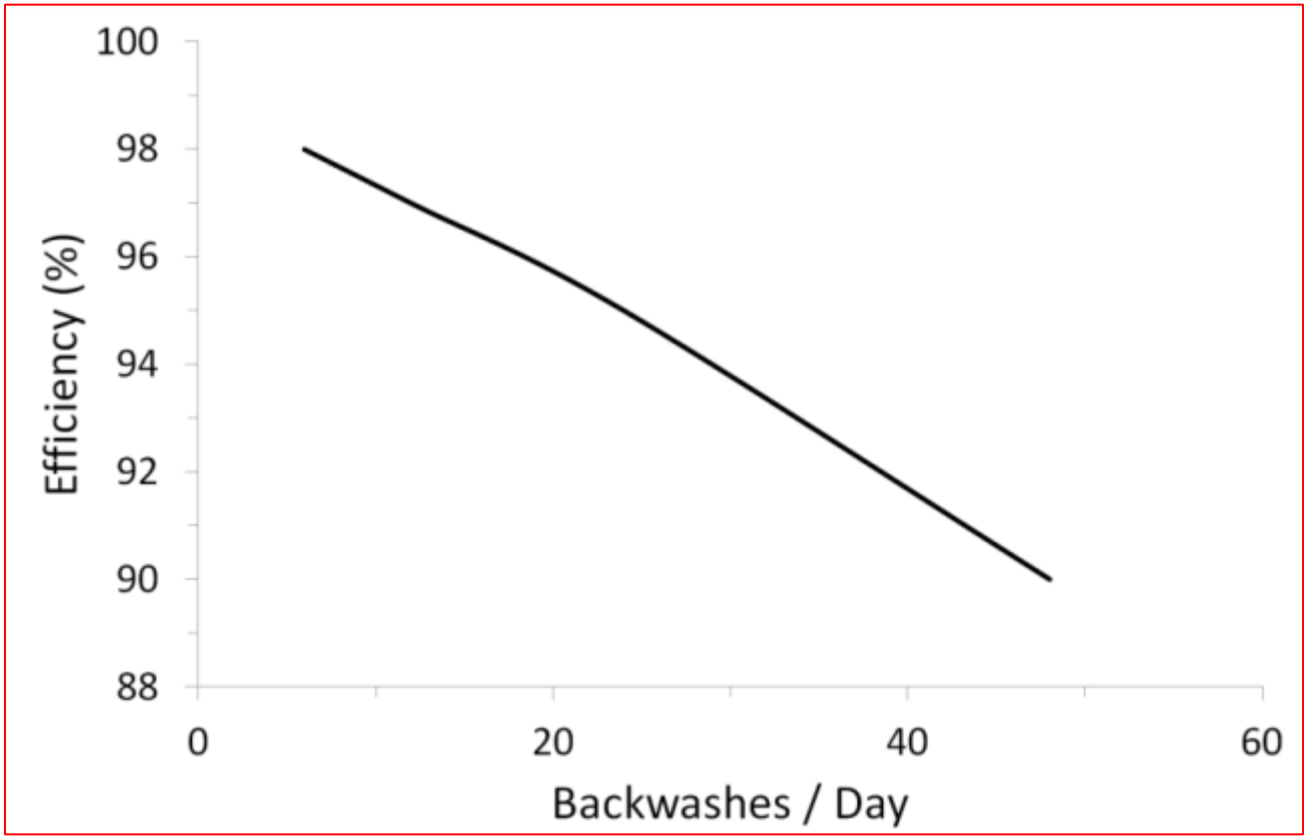


Cleanings

- Three different types of cleanings are done in order to maintain sustainable operation of ultrafiltration and thus controlling trans-membrane pressure

Cleaning	Foulant	Chemicals	Frequency
Backwash (BW)	Particle	-	Hours
Chemical Enhanced Backwash (CEB)	Biological	Chlorine	Days
Cleaning in Place (CIP)	Organic	Base	Month
Cleaning in Place (CIP)	Inorganic	Acid	Month

Backwash Contribution to Efficiency*

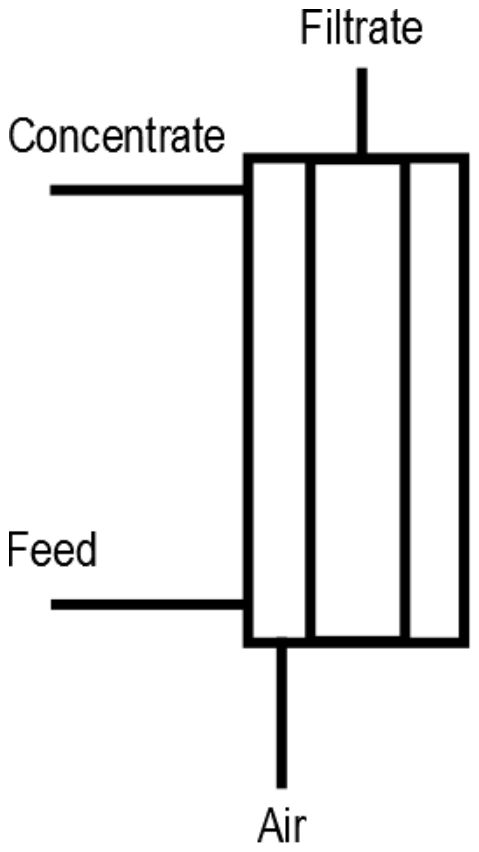


*Efficiency=Availability * Operational Recovery

Backwash Sequence

- Backwash sequence consists of five cleaning steps which are executed in order one after the other.

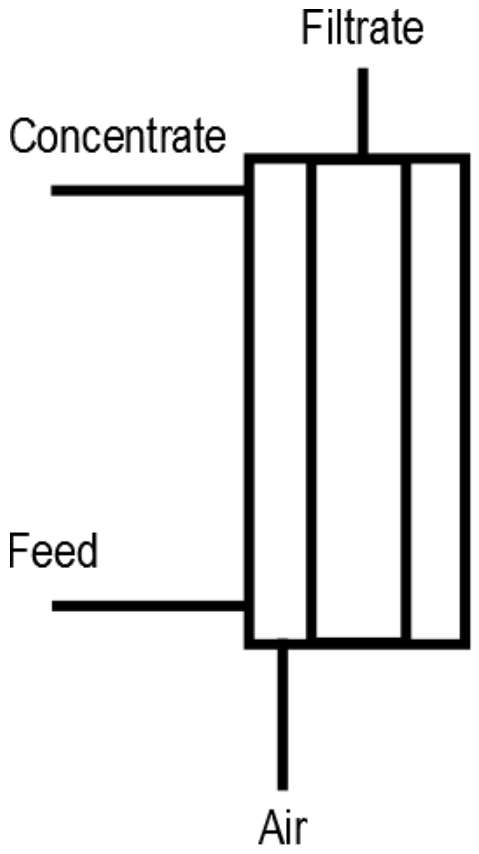
Order	Steps	Description
1	AS	Air Scour
2	D	Drainage
3	BWT+AS	Backwash Top with Air Scour
4	BWB	Backwash Bottom
5	FF	Forward Flush



Air Scour

- Air Scour is used to shake the fibers creating a shearing effect between the different fibers which causes fouling to detach from membrane surface

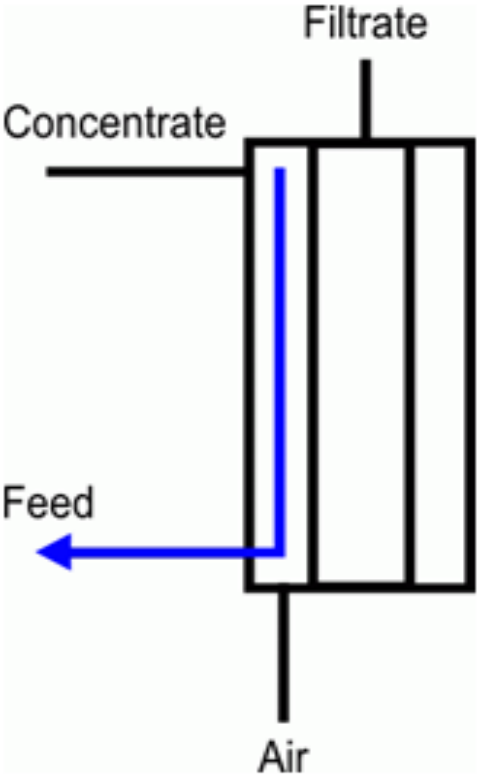
Order	Steps	Description
1	**AS**	**Air Scour**
2	D	Drainage
3	BWT+AS	Backwash Top with Air Scour
4	BWB	Backwash Bottom
5	FF	Forward Flush



Drainage

- Drainage is used to empty the module after an Air Scour, so that all the dirtiness is removed.

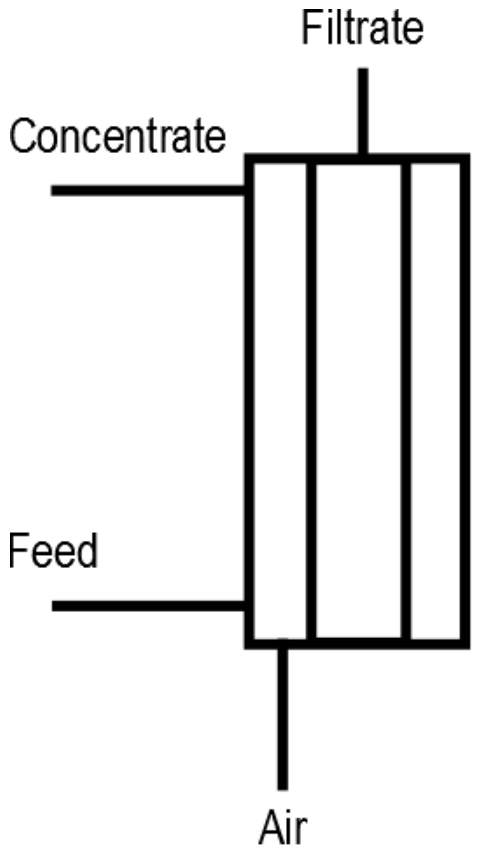
Order	Steps	Description
1	AS	Air Scour
2	**D**	**Drainage**
3	BWT+AS	Backwash Top with Air Scour
4	BWB	Backwash Bottom
5	FF	Forward Flush



Backwash Top With Air Scour

- Backwash Top with Air Scour is used to force filtrated water to reversely pass through the fibers to unblock the pores and leave through the upper part of the module; air is fed to the module to create a shearing effect between the shaking fibers causing fouling to detach from membrane surface

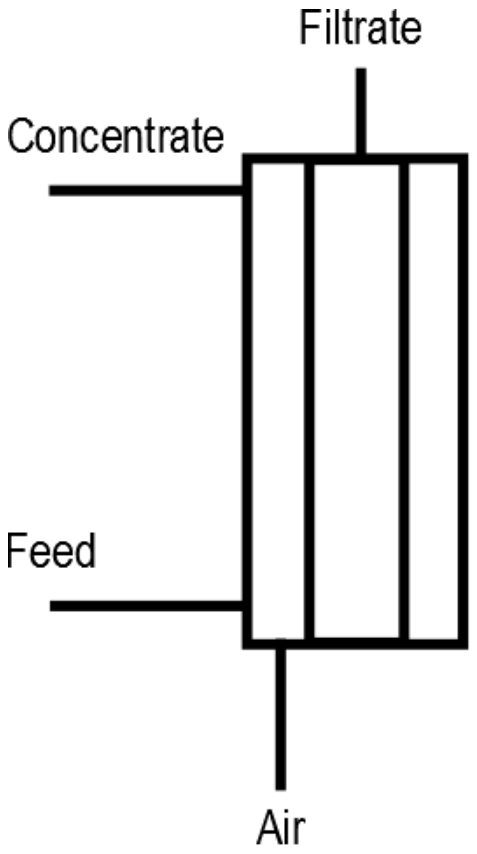
Order	Steps	Description
1	AS	Air Scour
2	D	Drainage
3	**BWT+AS**	**Backwash Top with Air Scour**
4	BWB	Backwash Bottom
5	FF	Forward Flush



Backwash Bottom

- Backwash Bottom is used to force filtrated water to reversely pass through the fibers to unblock the pores and leave through the bottom part of the module

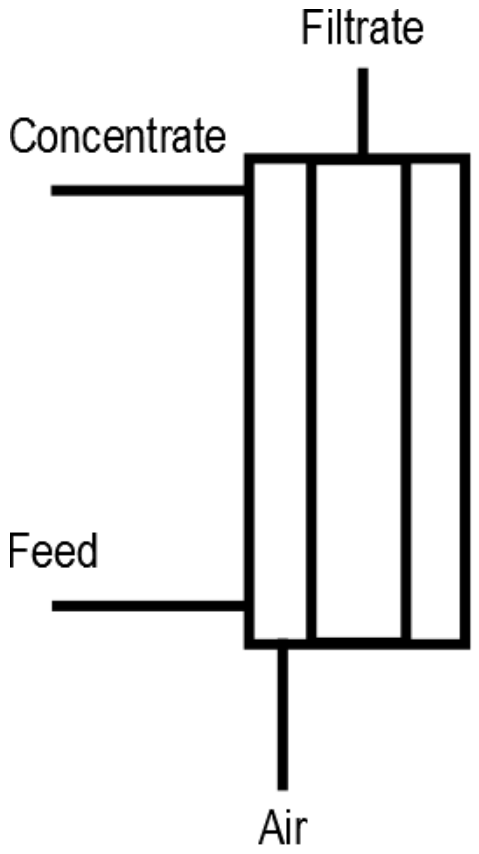
Order	Steps	Description
1	AS	Air Scour
2	D	Drainage
3	BWT+AS	Backwash Top with Air Scour
4	**BWB**	**Backwash Bottom**
5	FF	Forward Flush



Forward Flush

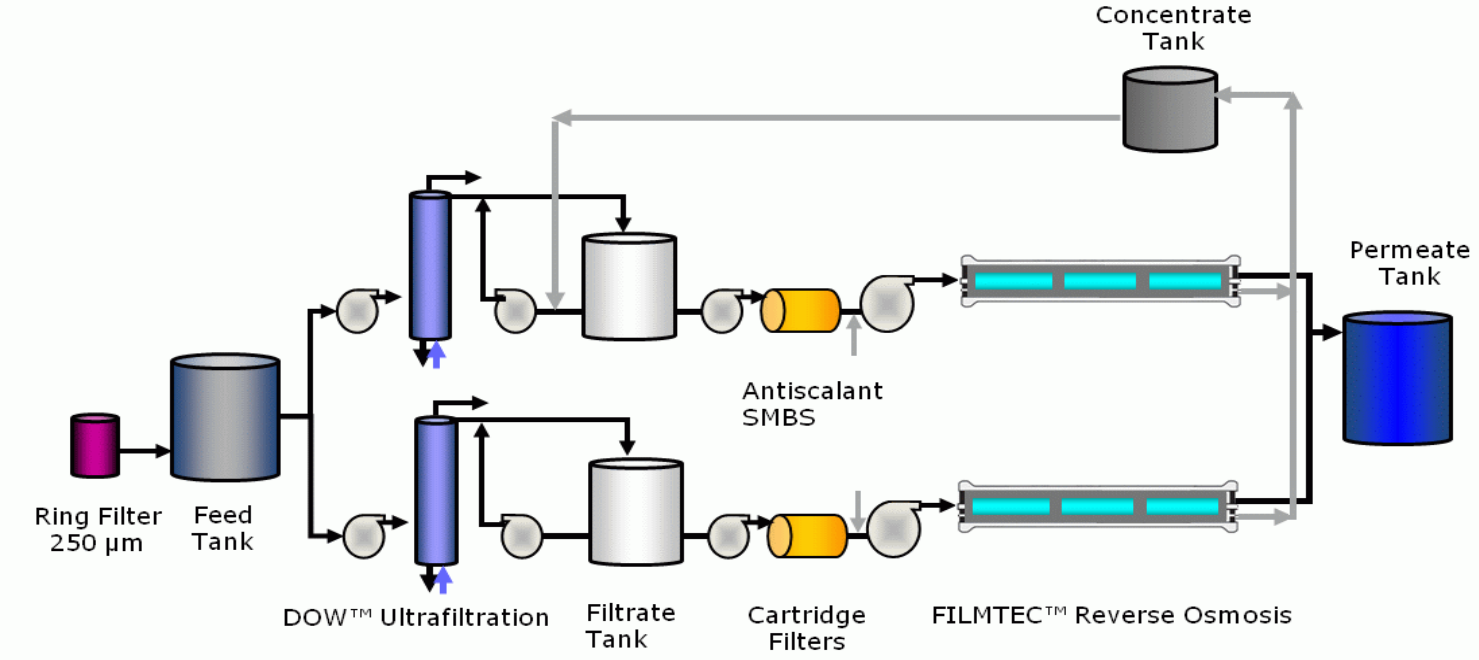
- Forward Flush is used to create a shearing effect above the fibers so that fouling can detach the membrane surface

Order	Steps	Description
1	AS	Air Scour
2	D	Drainage
3	BWT+AS	Backwash Top with Air Scour
4	BWB	Backwash Bottom
5	**FF**	**Forward Flush**



Desalination Plant

- Desalination plants integrate ultrafiltration pretreatment to remove particles such as colloids, algae, bacteria, viruses and macromolecules
- This allows operating reverse osmosis membranes at higher flux with less fouling. Therefore, reverse osmosis can focus on reducing salt content from water instead of also eliminating particles



Results from Statistically Designed Experiment

- Backwash cleaning steps were reduced from 5 to 2
- Efficiency is increased from 88% to 95%, having the plant operating 96% of time with a 98% recovery
- Chemicals savings are increased to 9%

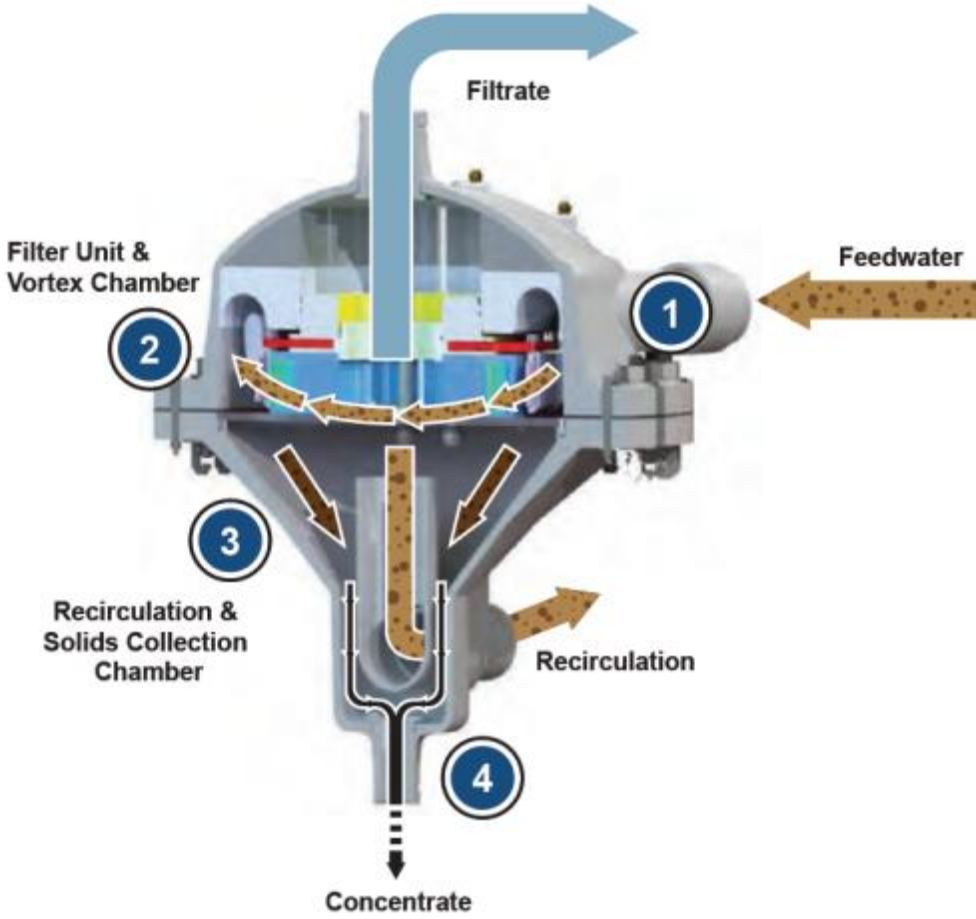
Exp	Frequency	Steps	Time	Recovery	Efficiency	Chemicals
-	30 min	5	91%	96%	88%	0.32 mg/l
1	30 min	2	96%	98%	95%	0.29 mg/l
Total	**-**	**60%**	**5%**	**2%**	**7%**	**9%**

TEQUATIC™ PLUS Fine Particle, Self-Cleaning Filters

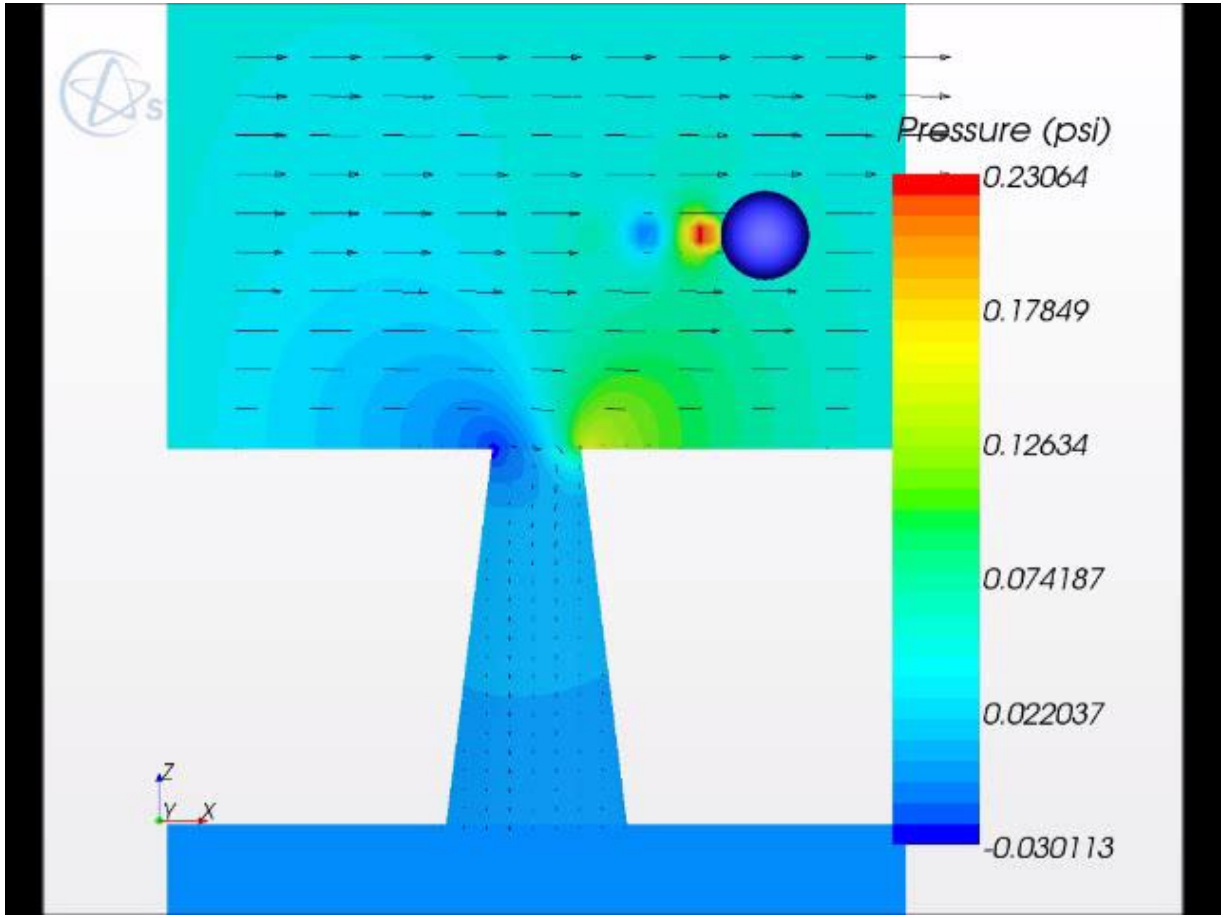
- Nominal 10-50 um cutoff, 50-10,000 mg/L
- High recovery, low maintenance
- Outperforms competitive solutions for targeted applications
  - Produced Water disposal wells
  - Pre-RO treatment
  - Pulp & Paper, Food & Beverage

TEQUATIC™ PLUS Operation

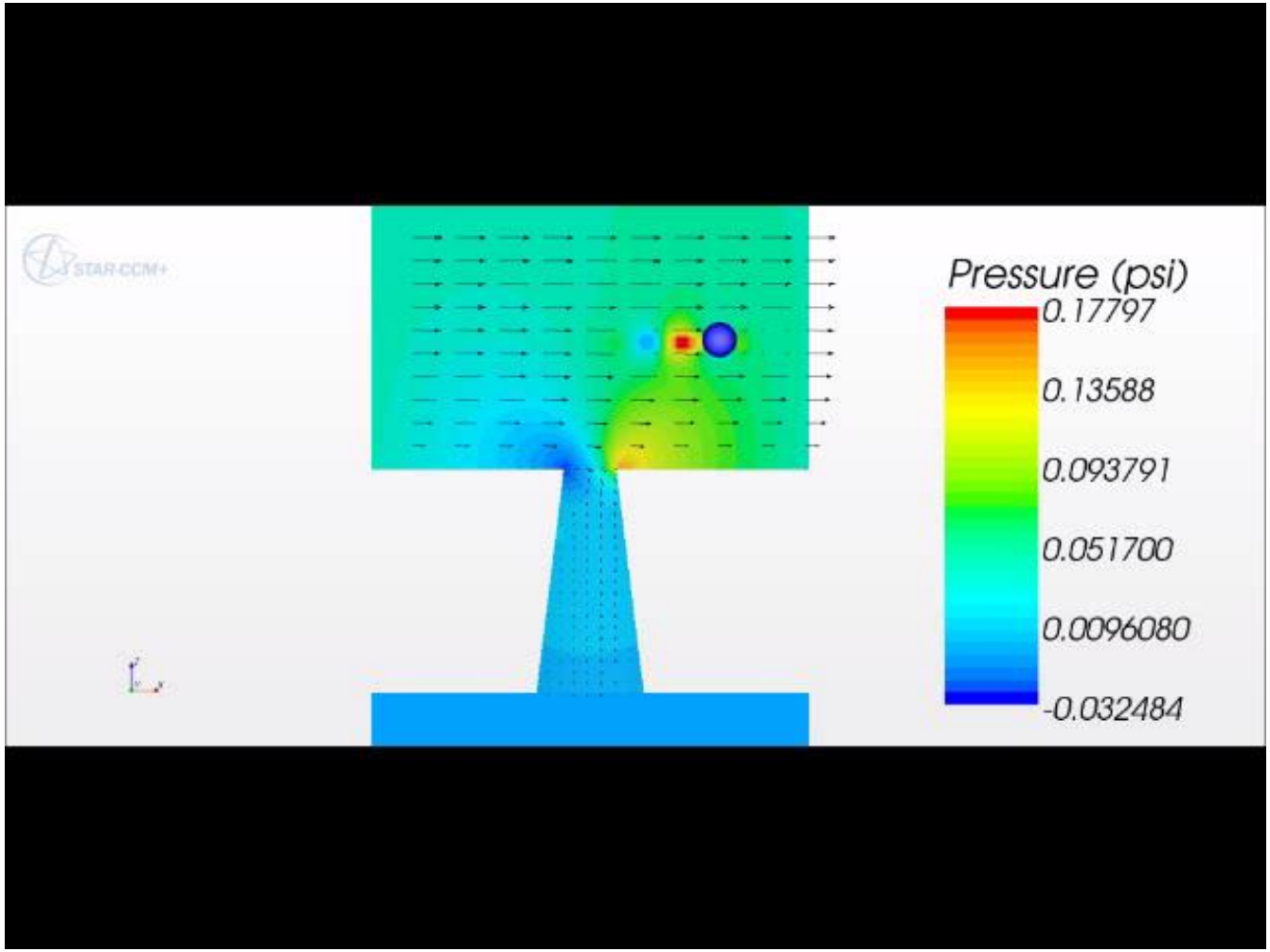
1. Centrifugal force pushes dense particles outward
2. Vortex chamber continuously cleans filter
3. Solids are recirculated
4. Settled solids are purged



30 Micron Particle, 30 Micron Pore



20 Micron Particle, 30 Micron Pore



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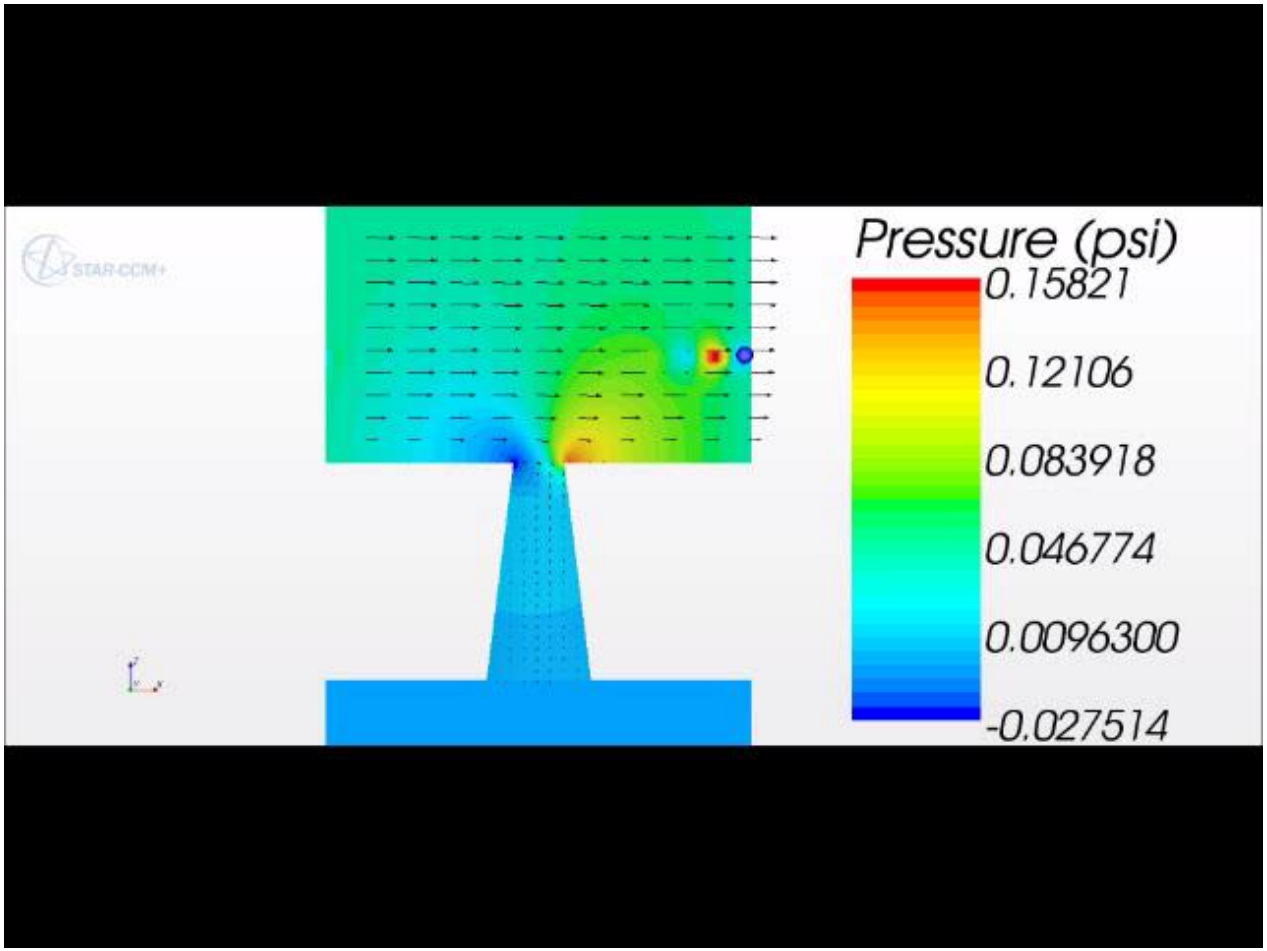

Summary, Examples and Expectations for the Future

- Refocused research on dominating forces within RO OpEx and CapEx
  - Fouling, configurations, element, selected rejection
  - Broader application requirements
- High operational flux UF membranes
  - Optimized cleaning
  - Higher solids
- Reliable, lower cost self-cleaning microscreens

Thank You

Dow Water & Process Solutions

Innovation that works harder to realize advancement in human progress

www.dowwaterandprocess.com