LG Chem

LG Water Solutions

BGNDRF 1st Annual WIN Workshop

LG Chem Brackish Water RO Membranes

Pilot testing in BGNDRF

September 19, 2018
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LG Water Solutions Overview

History of innovation and rapid growth

- **2005** ▪ NanoH_2O founded in Los Angeles, California (USA).
- **2006** ▪ Patents on Nanocomposite membrane technology filed.
- **2008** ▪ Industry's highest flux and rejection SWRO membrane introduced to the market.
- **2011** ▪ Palmachim installation awarded
- **2014** ▪ LG Chem acquired NanoH_2O and formed LG Water Solutions.
- **2015** ▪ Opened manufacturing facility in Cheongju, Korea.
- **2016** ▪ Sohar desalination project in Oman awarded (250,000 m^3/day).
- **2017** ▪ Became No.1 in new large scale seawater desalination.
- **2018** ▪ BWRO contracts for major facilities in the US awarded (OCWD, SCVWD, West Basin, total ca. 100,000 m^3/day)

Core Technology : Thin-Film Nanocomposite (TFN)

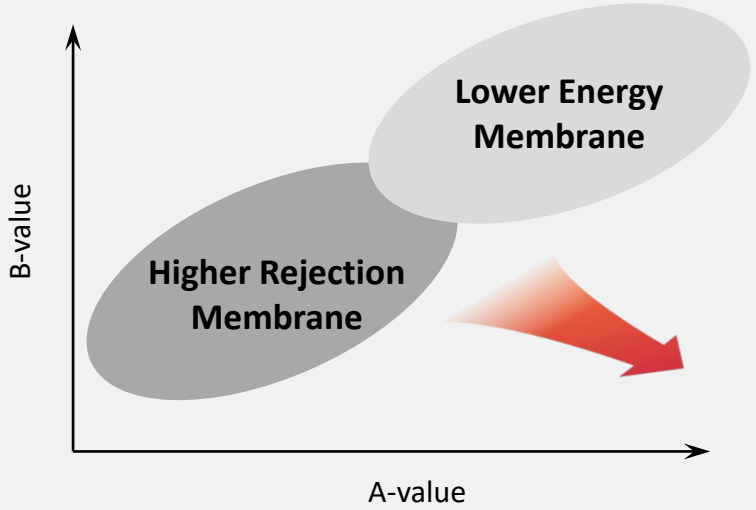
Performance comparison between TFN vs. TFC (Conventional Thin-Film Composite)

Performance of RO membranes is defined by **two parameters**:

Water Flux $J_w=A(\Delta P-\Delta\pi)$

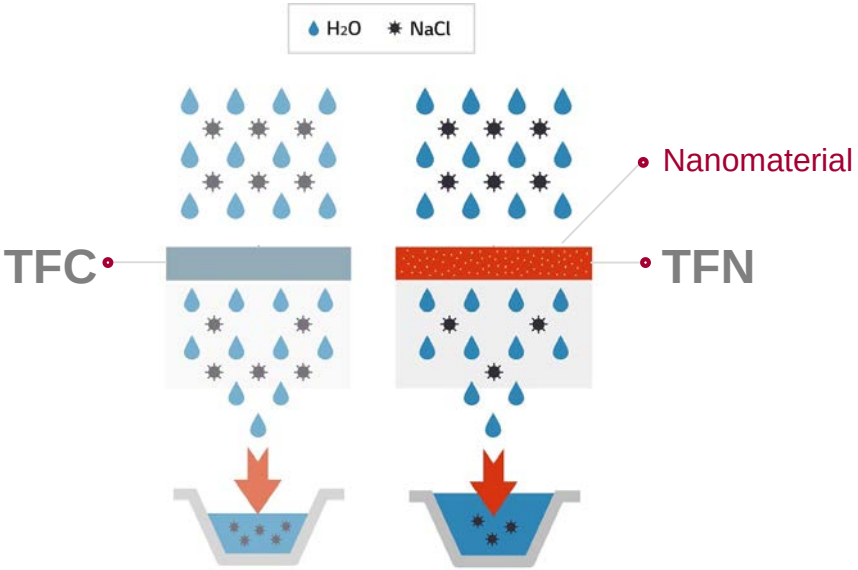
Solute Flux $J_s=B\Delta C$

- **A-value:** water permeability coefficient
- **B-value:** solute permeability coefficient



The goal is to get **higher A-value** and **lower B-value**

LG NanoH$_2$O TFN technology improves water permeability of RO membranes without compromising salt rejection



01 **Increased** Water Production

02 **Highest** Salt Rejection in the Industry – 99.85%

03 **Patented Technology** (128 Patent-Pending)

SWRO Products

Global project wins driven by performance

LG SW SR, GR and R High Rejection Membranes

Well suited for high feed TDS and high quality permeate requirements

LG SW ES Energy-Saving Membranes

Well suited for low feed TDS and low temperature seawater applications

* **8-inch** spiral wound membrane

Product	Active Area ft² (m²)	Permeate Flow Rate GPD (m³/d)	Minimum Salt Rejection (%)	Stabilized Salt Rejection (%)	Boron Rejection (%)	Feed Spacer (mil)
LG SW 400 SR	400 (37)	6,000 (22.7)	99.7	99.85	93	28 or 34
LG SW 440 SR	440 (41)	6,600 (25.0)	99.7	99.85	93	28
LG SW 400 GR	400 (37)	7,500 (28.4)	99.7	99.85	93	28 or 34
LG SW 440 GR	440 (41)	8,250 (31.2)	99.7	99.85	93	28
LG SW 400 R	400 (37)	9,000 (34.0)	99.7	99.85	93	28 or 34
LG SW 440 R	440 (41)	9,900 (37.0)	99.7	99.85	93	28
LG SW 400 ES	400 (37)	13,700 (52.0)	99.6	99.80	89	34
LG SW 440 ES	440 (41)	15,070 (57.0)	99.6	99.80	89	28

Test condition: 32,000ppm NaCl @ 25℃, 800psi(55bar), pH 8, Recovery 8%. Permeate flows for individual elements may vary +/- 15%.

Recent Large Project Wins

Most large project wins over the last two years - becoming an SWRO leader

BWRO Products

Superior quality leads to repeat customers

LG BW R High Rejection Membranes

Well suited for high salinity feed water and high quality permeate requirements

LG BW ES and UES Energy-Saving Membranes

Well suited for low salinity feed water and energy-saving applications

LG BW AFR Anti-Fouling Membranes

Well suited for feed water under harsh conditions

* **8-inch** spiral wound membrane

Product	Active Area ft² (m²)	Permeate Flow Rate GPD (m³/d)	Minimum Salt Rejection (%)	Stabilized Salt Rejection (%)	Feed Spacer (mil)
LG BW 400 R	400 (37)	10,500 (39.70)	99.5	99.6	34
LG BW 440 R	440 (41)	11,550 (43.70)	99.5	99.6	28
LG BW 400 ES	400 (37)	10,500 (39.70)	99.5	99.6	34
LG BW 440 ES	440 (41)	11,550 (43.70)	99.5	99.6	28
LG BW 400 AFR	400 (37)	10,500 (39.70)	99.5	99.6	34

Test condition: 2,000ppm NaCl @ 25℃, 225psi (15.5bar), pH 8, Recovery 15%. Permeate flows for individual elements may vary +/- 15%. [R, AFR]
2,000ppm NaCl @ 25℃, 150psi (10.3bar), pH 8, Recovery 15%. Permeate flows for individual elements may vary +/- 15%. [ES]

Globally Recognized BWRO Performance

Deliver reliable performance in a wide range of industries for the world's largest companies

Waste Water Reuse

"NEW PROJECTS WIN"

- Silicon Valley Advanced Water Purification Center in SCVWD
- Ground Water Replenishment System in OCWD
- Edward C. Little Water Recycling Facility in West Basin
- Scottsdale Water Campus

Power Generation

- الشركة السعودية للكهرباء Saudi Electricity Company
- KEPCO

Petrochemical / Refinery

- PETROBRAS
- IndianOil
- PEMEX

Semiconductor / Display

- LG Display
- infineon
- Panasonic

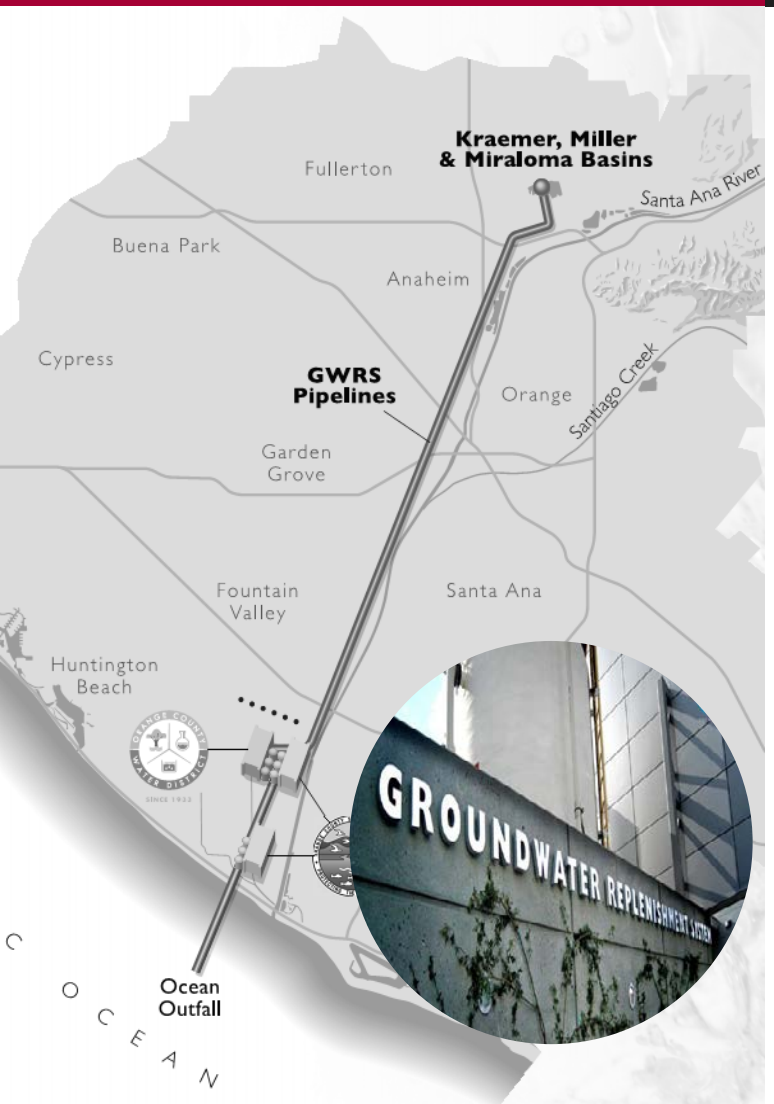
Food & Beverage

- Coca-Cola
- pepsi

Orange County Water District

LG Chem will install energy-saving LG BWRO membranes at the Groundwater Replenishment System (GWRS) in California, the world's largest water purification system for indirect potable reuse

Location



Project Snapshot

Operated By	Orange County Water District
Start-Up Date	October 2018
Feed Water Intake	Municipal wastewater plant secondary effluent
Application	Groundwater recharge for indirect potable reuse and injection for seawater intrusion barrier
Configuration	Three-stage, 3 RO units, 150 pressure vessels per train, with 7 elements per pressure vessel.
Recovery	85%
Project Capacity	15 MGD (56.8 MLD)
Total Number of LG Chem NanoH2O™ Elements	3150
LG Chem NanoH2O™ Membrane Model	LG BW 400 ES
Feed Temperature Range	79° - 84° F (26°- 29° C)

RO Membrane Qualification Program

Operating Parameters and Cleaning In Place

- A dedicated PV for the qualification program
- Minimum of one (1) year of operation if initial flux is acceptable
- Specific Flux above 0.085 gfd/psi
- Maintain 55% Recovery
- Monitor Permeate Water Quality
- One (1) standard CIP and one (1) aggressive CIP

Parameter	Standard Cleaning	Aggressive Cleaning
Solution(1)	2% (wt./wt.) STP(2) 0.2% (wt./wt.) DDBS(3)	3% (wt./wt.) STP(2) 0.3% (wt./wt.) DDBS(3)
Cycling	30 min. circulate and 60 min soak (repeat three times)	30 min. circulate and 60 min soak (repeat three times)
Flow rate	38 – 39 gpm (8.6 – 8.9 m^3/hr)	38 – 39 gpm (8.6 – 8.9 m^3/hr)
pH	11.0 ± 0.5	12.0 ± 0.5
Temperature	90 – 100 °F (32.2 – 37.8 °C)	90 – 100 °F (32.2 – 37.8 °C)(4)

(1). Solutions made up using RO product water

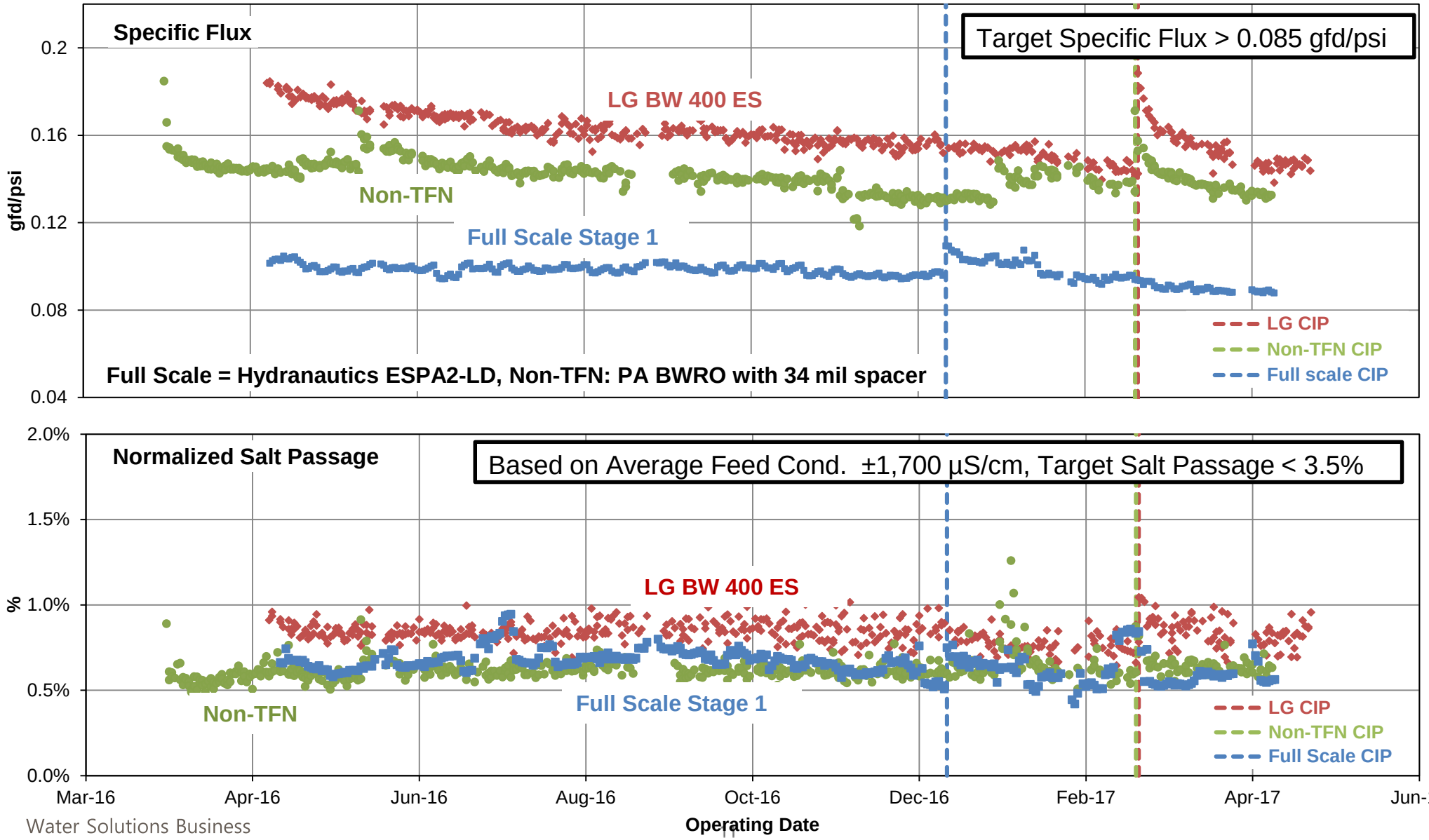
(2). Sodium tripolyphosphate LD light density (or equivalent)

(3). Sodium dodecylbenzene sulfonic acid (or equivalent)

(4). LG had requested the Client to perform the aggressive CIP at ambient temperature (28-30 °C) when cleaning with pH 12.

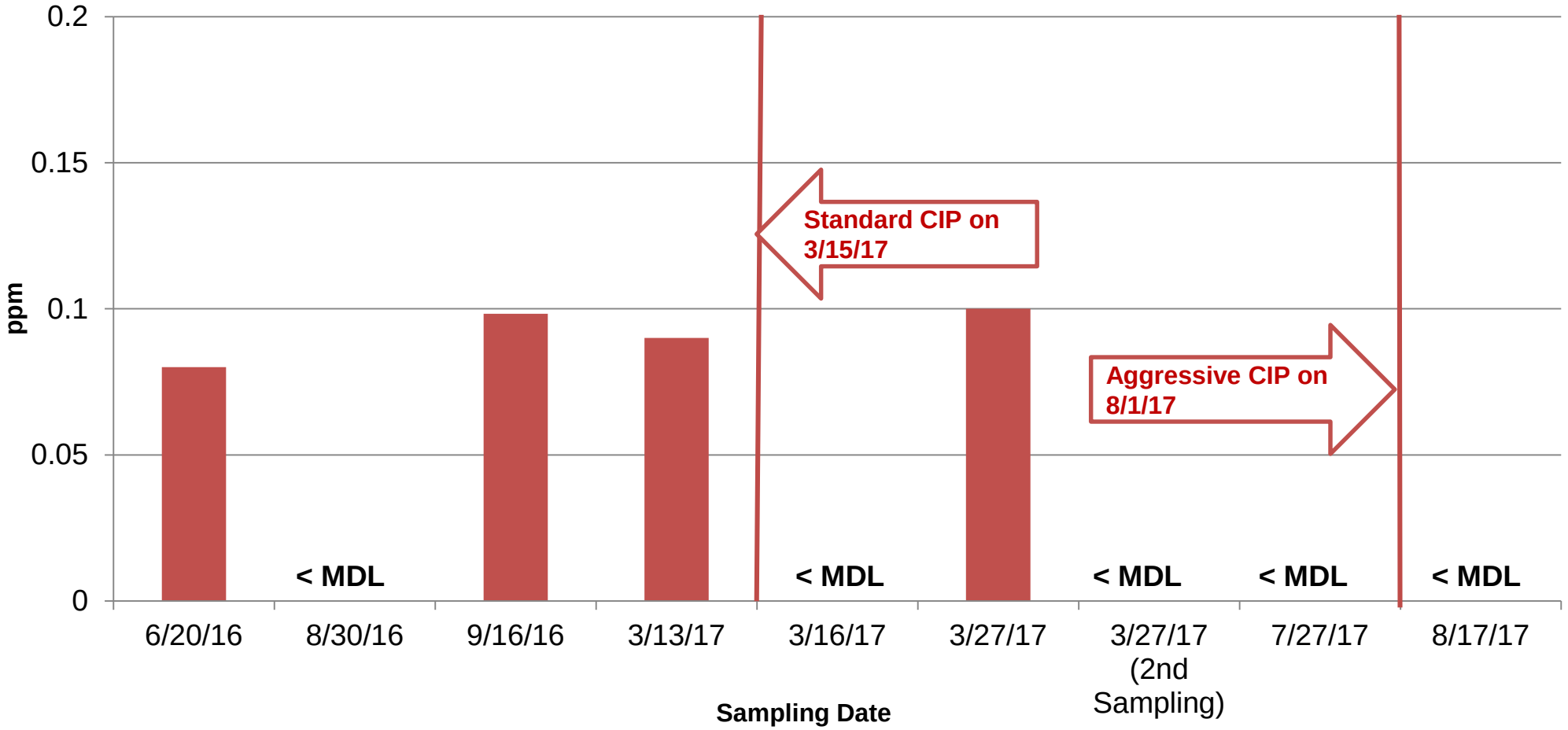
Orange County Water District

LG Chem vs. Non-TFN Membrane Comparison Data



Membrane Performance

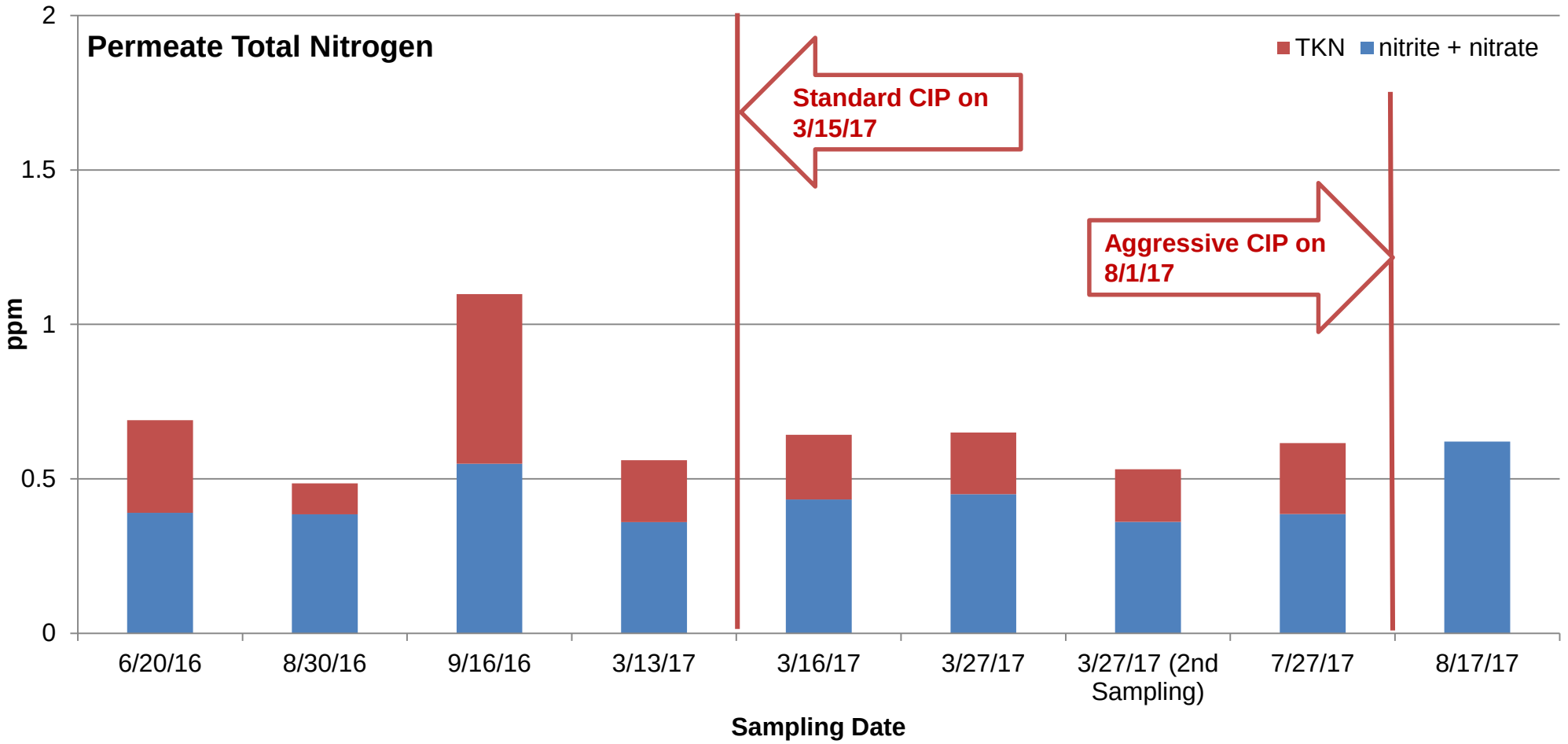
LG BW 400 ES Targeted Permeate Organic Carbon



Feed TOC = 5 – 10 ppm
Target Permeate TOC < 0.5 ppm
MDL (Method Detection Limit) = 0.0331 ppm

Membrane Performance

LG BW 400 ES Targeted Permeate Total Nitrogen



Feed TN = 11 – 16 ppm

Target Permeate TN < 5.0 ppm

Santa Clara Valley Water District

LG Chem will install energy-saving LG BWRO membranes at the Silicon Valley Advanced Water Purification Center in California operated by SCVWD

Location

Silicon Valley Advanced Water Purification Center

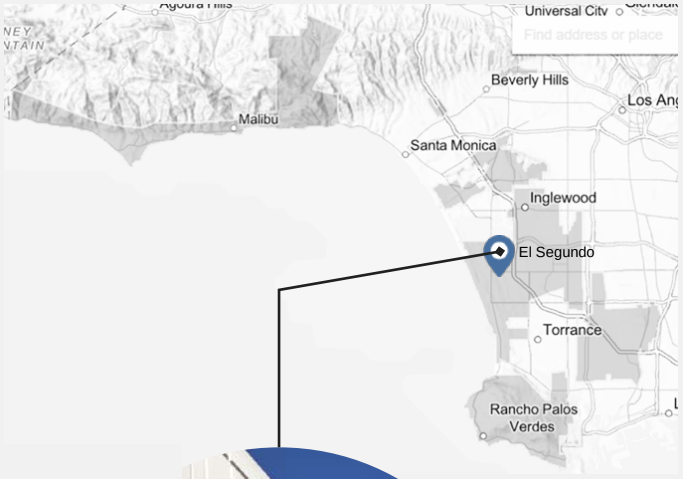
Project Snapshot

Operated By	Santa Clara Valley Water District
Start-Up Date	October 2018
Feed Water Intake	Municipal wastewater facility secondary effluent
Application	Groundwater recharge for indirect potable reuse
Configuration	Two-stage, 3 RO trains, 80 pressure vessels per train, with 7 elements per pressure vessel.
Recovery	80 - 85%
Project Capacity	8 MGD (30.3 MLD)
Total Number of LG Chem NanoH2O™ Elements	1680
LG Chem NanoH2O™ Membrane Model	LG BW 400 ES
Feed Temperature Range	61° - 82° F (16°- 28° C)

West Basin Municipal Water District

LG Chem was awarded the membrane replacement contract to install anti-fouling BWRO membranes at Edward C. Little Water Recycling Facility (ECLWRF)

Location

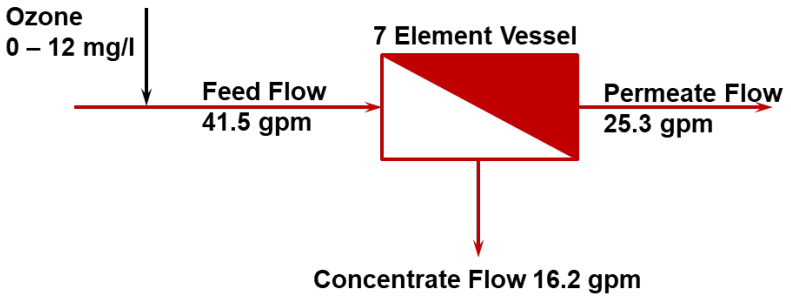


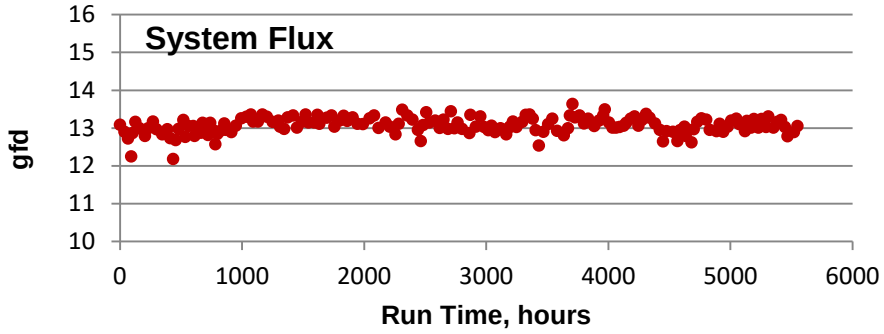
Project Snapshot

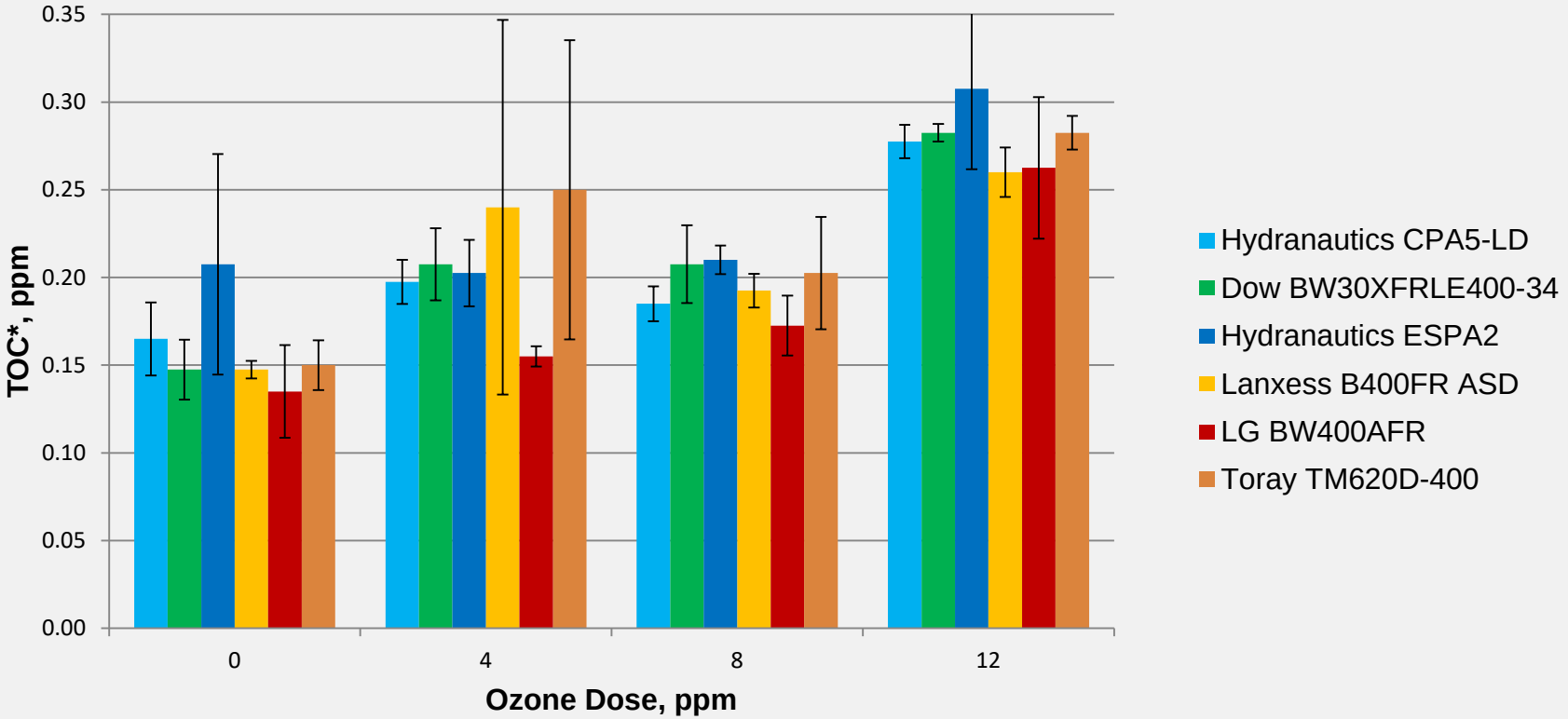
Operated By	West Basin Municipal Water District
Start-Up Date	October 2018
Feed Water Intake	Wastewater treatment plant secondary effluent, ozonated
Application	Groundwater recharge for indirect potable reuse and injection for seawater intrusion barrier
Configuration	One three-stage train with 126 pressure vessels, six (6) elements per vessel
Recovery	85%
Project Capacity	3 MGD (11.4 MLD)
Total Number of LG Chem NanoH2O™ Elements	756
LG Chem NanoH2O™ Membrane Model	LG BW 400 AFR
Feed Temperature, Average	81° F (27° C)

West Basin Municipal Water District

LG Chem anti-fouling membrane delivered best TOC removal in pretreatment ozonation pilot study



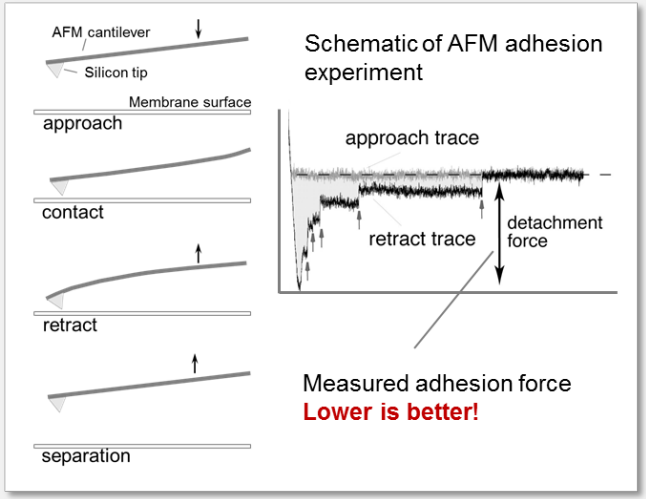


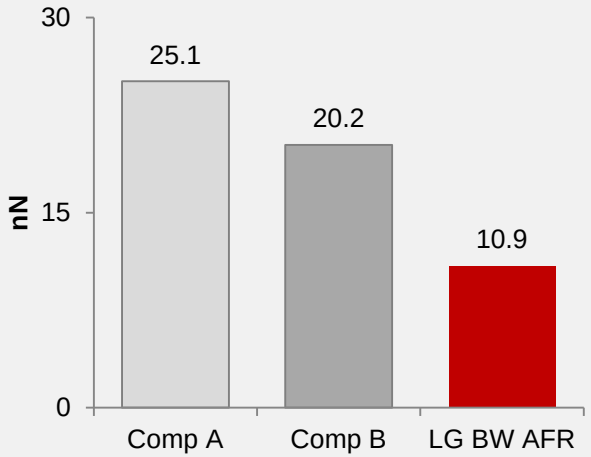


LG Chem BW Anti-Fouling Membrane

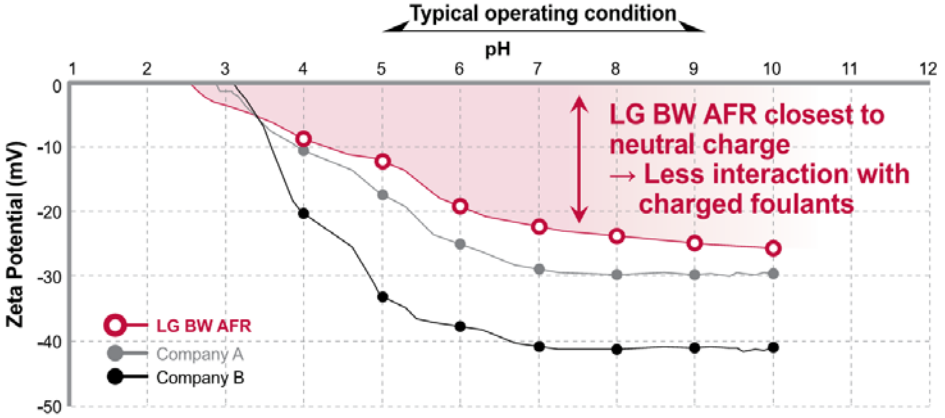
LG Chem has developed a BWRO membrane that combines the advantages of TFN (Thin-Film Nanocomposite) with anti-fouling (AF) characteristics

Surface Interaction (Adhesion by AFM)

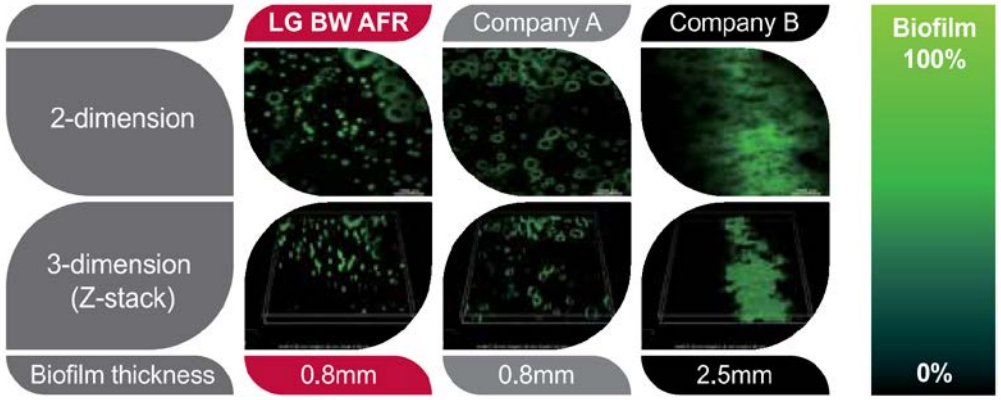




Surface Charge (Zeta-Potential)



Microbial Growth (*E.Coli*)



Research and Development

- LG Chem has three R&D centers with more than 4,800 researchers dedicated to developing innovative products
- LG Chem is continuing to develop next generation products incorporating nanotechnology to lead the future of RO

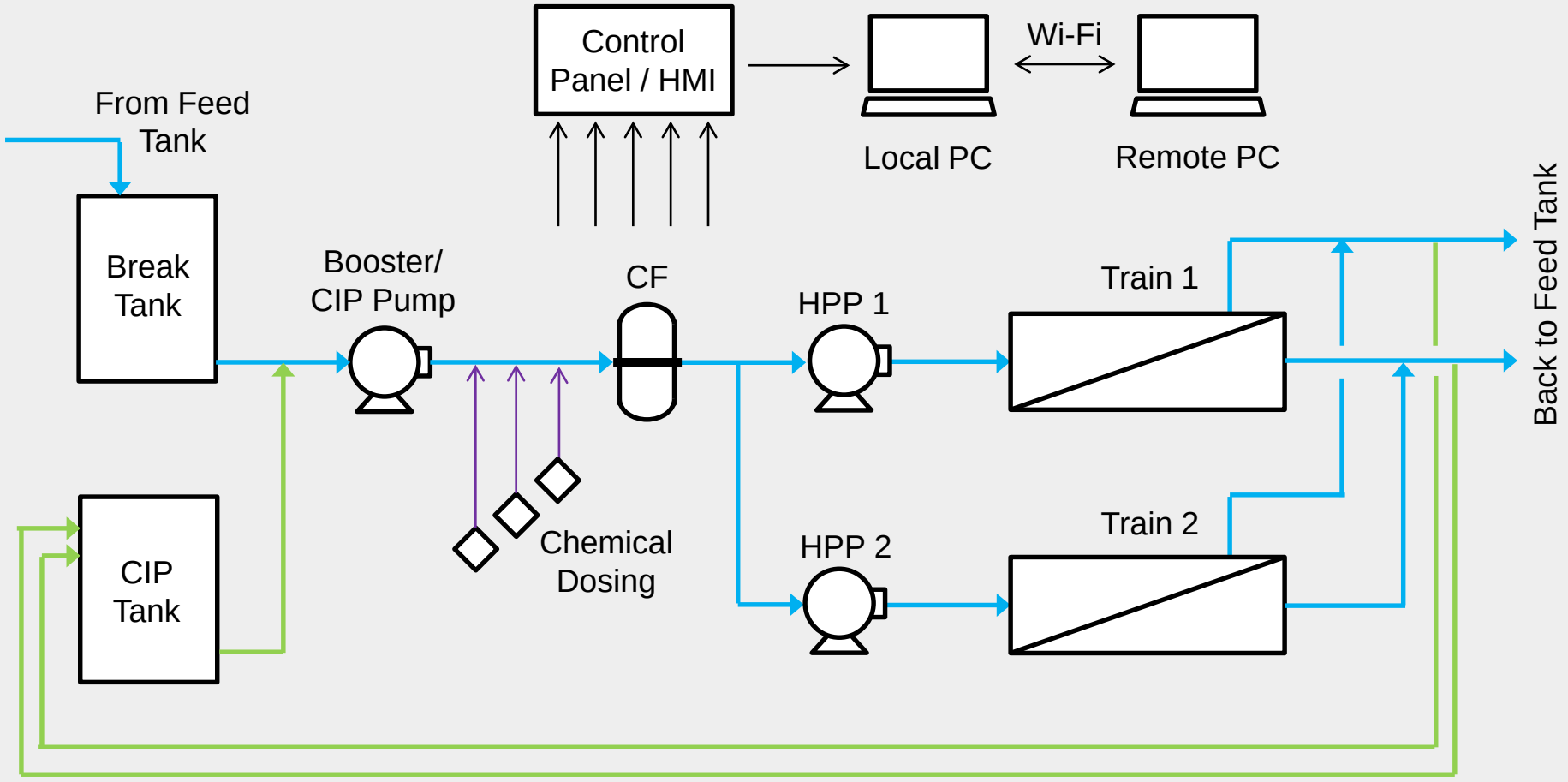
Pilot System Overview

Fully containerized pilot unit for verification of new and existing BW membranes

- Installed in Brackish Groundwater National Desalination Research Facility (BGNDRF), Alamogordo, NM in Jan 2017
- Fully containerized BWRO skid
- Two (2) trains in parallel
- Seven (7) elements per train
- Up to 75 GPM capacity
- CIP enabled
- Remote monitoring and data acquisition

Pilot System Overview

Flow Diagram



Thank you

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