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Agenda

- Ceramic Membrane Overview
- Hydraulic Cleaning Profiles Of Polymeric and Ceramic Membranes
- Boise River Pilot Study #1: Backwash Methods
- Boise River Pilot Study #2: Flux Step Up
- Filter Backwash Water Recovery Pilot Study


MF/UF Systems:
Obvious and Less than Obvious Impacts
Replacement Cost
Fiber Breakage
Fouling
Flux Degradation
Energy Costs
Cold Water Design Impact
Robustness To Upsets:
Downtime & Memb. Life Impact
Pretreatment CAPEX & OPEX
Waste Volume
CIP Cycle Frequency vs.
Membrane Life & Opex
Water Recovery

Ceramic Vs. Polymeric Membranes

Polymeric MF/UF

- 5-10 year life typical
- Fiber break potential
- Lower flux (30-60 GFD typical)
- Lower TMP limits (<40psi)
- Oxidant exposure limited
- pH limited (2-12; 3-10)
- Lower solids and very low oil limits

Ceramic MF/UF

- 10-20 year life
- No fibers to break
- Higher flux (100-200 GFD typical)
- Higher TMP limits (>100psi)
- High oxidant exposure
- Wide pH range (1-13)
- High solids and oil tolerance

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Applications For Ceramic Membranes

Small Tubular Style

1-5 ft2 (0.1-0.5 m2) area / piece

More “Niche” Applications (Higher Value)

Much More Expensive Than Polymeric UF/MF

Larger Monolith Style

80-270 ft2 (7-25 m2) area / piece

More “Mainstream” Water & Waste Water Reuse

More Competitive With Polymeric UF/MF

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Producing Ceramic Membranes

Raw Materials Preparation

Extrusion

Drying Furnace

Nano Particle Coating Process

Sintering Oven

Potting and Module Assembly

Quality Assurance Test

Technology Team

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Nanostone – Ceramic Module Differentiation

Tubular

Legacy Ceramic Technology

(-) Low surface area/piece
(-) High manufacturing cost

Monolith

(+) High Surface area
(+) Reduced manufacturing cost
(-) Green bodies deformation lowers yield
(-) Post firing machining adds cost

Segmented

(+) High surface area
(+) Segments- no machining
(+) Segments – high yield
(+) Lowest cost to mfg.

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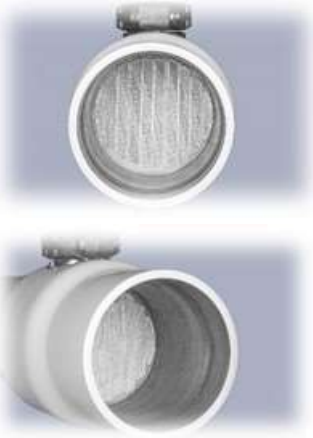
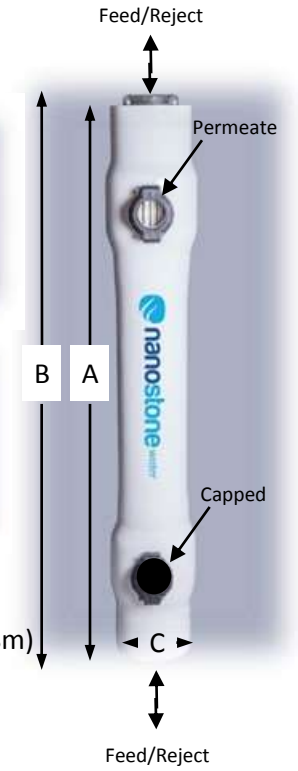
Nanostone – Ceramic Module

High Level Specifications

- Alumina Membrane, FRP Vessel, Duplex Port
- Nominal 1 Log Removal: 30nm (0.03 micron)
- 19m^2 (205ft^2) Active Area
- Inside / Out Flow Path (2.4mm channel)
- 10Bar (150 psi) Rated Pressure
- Dead End Flow or Minimal Crossflow
- Backwash at 1-3 Times Filtration Flux



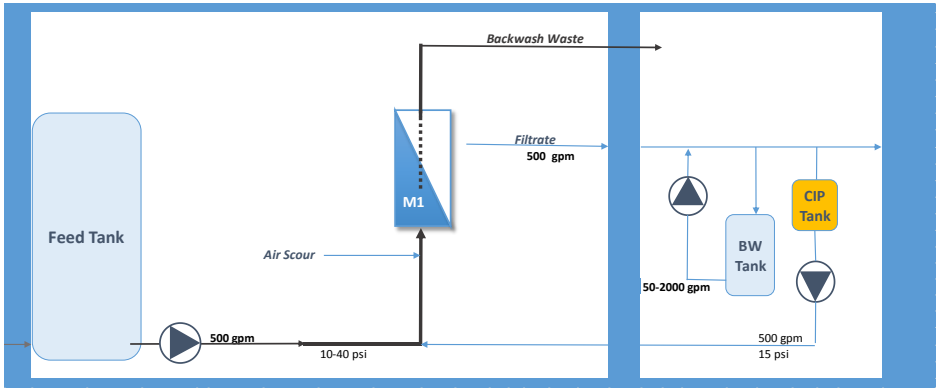


Connections: 3-inch Grooved Coupling
"A" Overall Vessel Height: 66.14" (1.68m)
"B" Port to Port Height: 67.5" (1.7m)
"C" Vessel diameter: 8.43" (0.21m)

Polymeric Membrane Hydraulic Cleaning

Polymeric Pressurized UF/MF Systems

- Typically dead end filtration or low crossflow filtration mode
- Periodic backwash at 10-400% of filtration flow
- Slow ramp up of backwash pump (reduce fiber breaks)
- Feed flush often used
- Air scour often used to break up sludge (outside/in)



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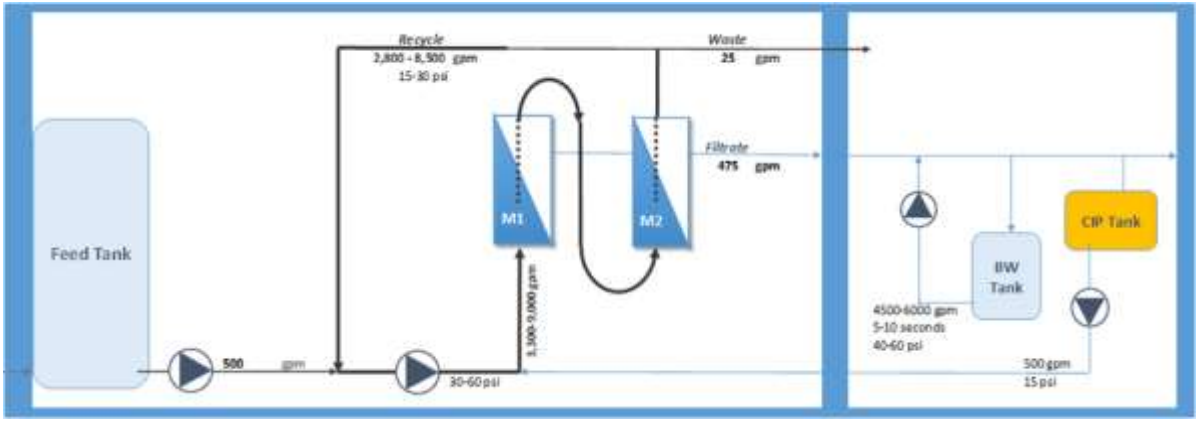
Ceramic Membrane Hydraulic Cleaning

Crossflow Ceramic UF/MF Systems

- Crossflow velocity 1-3 m/s (3-10 ft./sec)
- Crossflow pumps/pipes at 5-20X filtrate flow
- Backwash 10-15X filtrate flow
- Backwash with pump or hydro pneumatic (tank, valve)



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Ceramic Membrane Hydraulic Cleaning

Dead End Ceramic UF/MF Systems

- High rate / pressure backwash @ 10X + filtration flow
- Backwash hydro pneumatic (tank, valve)
- Air Purge / Fast Drain Option

Veolia / Metawater Ceramic System Parker Colorado

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Cost Of Hydraulic Cleaning

Ceramic Module Costs Are Decreasing!

But What About The System Costs Around It?

- Crossflow pump capex/opex
- High rate backwash pipe size/material
- Hydro pneumatic system design

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Nanostone Ceramic Membrane Module Case Studies

Nanostone Ceramics Membrane Pilots

Mini Module

- 3 m^2/35 ft^2
- in PVC Pipe

Full Scale Module

19 m^2/205 ft^2

in FRP vessel

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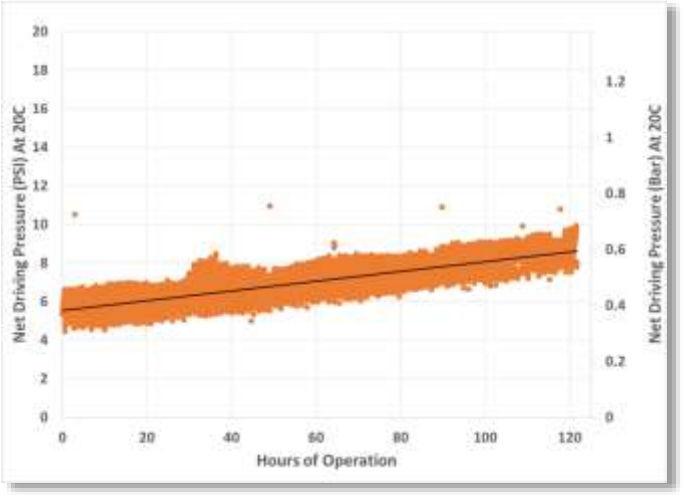
Boise River Study #1: Hydraulic Cleaning

Test #1: Typical Ceramic Membrane Hydraulic Clean (using fast ramp compressed air)



- Dead end filtration @ 170lmh (100gfd) flux for 60 mins
- 1 sec backwash @ 5 bar (72psi) @ 2400lmh (1400 gfd)
- 40 second Feed flush @ 100% filtration flow
- 98% recovery
- 0.0017 bar (0.025 psi) per hour pressure increase

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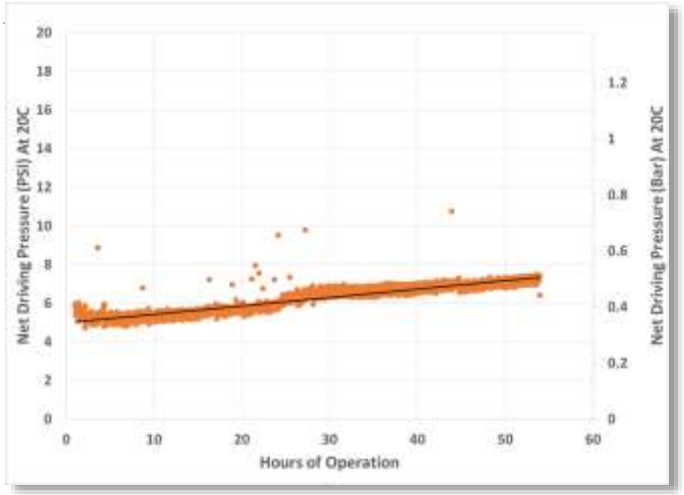
Boise River Study #1: Hydraulic Cleaning

Test #2: Typical Polymeric Membrane Hydraulic Clean (using slow ramp pump)



- Dead end filtration @ 170lmh (100gfd) flux for 20 mins
- 11 sec backwash @ ~ 1 bar (15psi) @ 340lmh (200 gfd)
- 10 second Feed flush @ 100% filtration flow
- 97% recovery
- 0.003 bar (0.04 psi) per hour pressure increase

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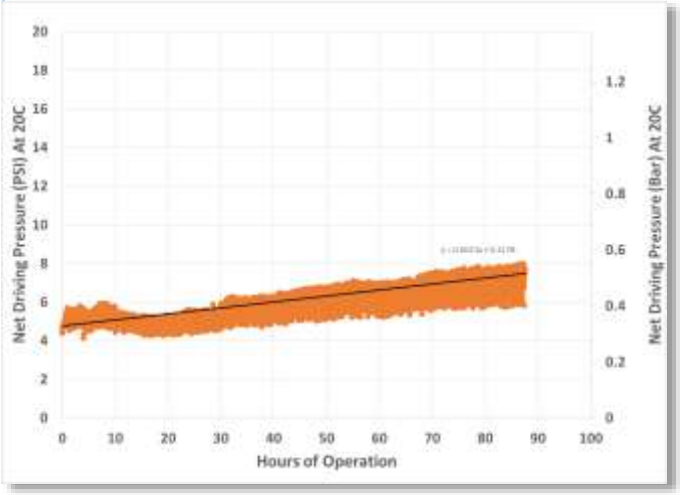
Boise River Study #1: Hydraulic Cleaning

Test #3: Hybrid Approach Hydraulic Cleaning (using fast pump ramp up or compressed air)



- Dead end filtration @ 170lmh (100gfd) flux for 20 mins
- 10 sec backwash @ ~ 1 bar (15psi) @ 340lmh (200 gfd)
- 40 second Feed flush @ 100% filtration flow
- 95% recovery
- 0.002 bar (0.03 psi) per hour pressure increase

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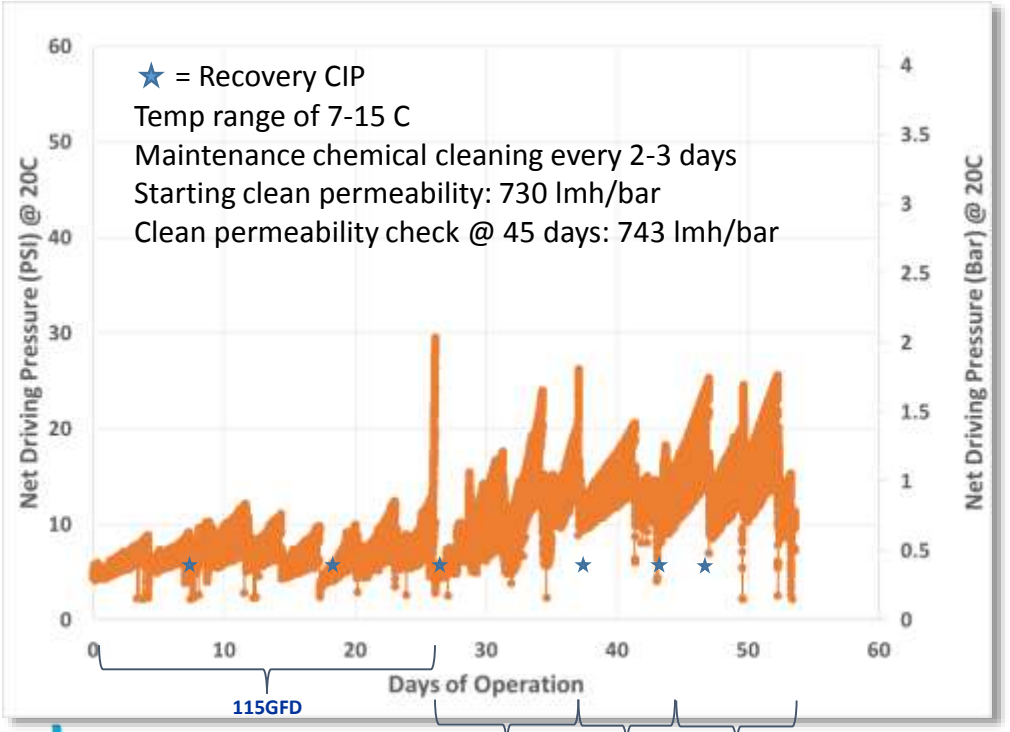
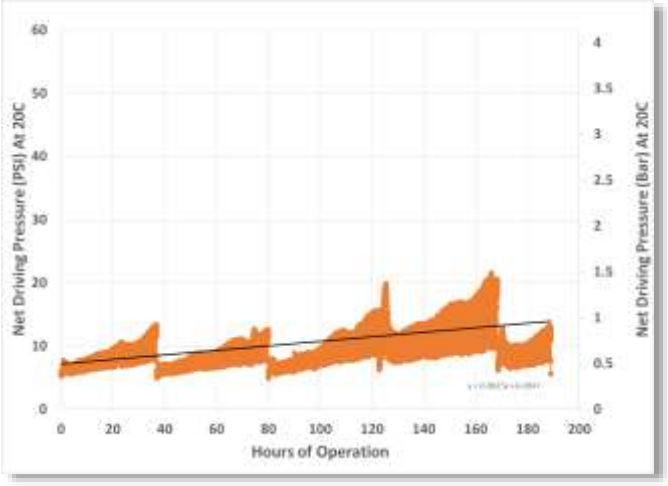
Boise River Study #2: Flux Step Up

Variety of Flux Rates, Coagulant Dosages, Operating Experiments
Feed turbidity 3-10 NTU. Permeate turbidity 0.02 – 0.08 NTU
Temperature: 45-60F (7-15C)

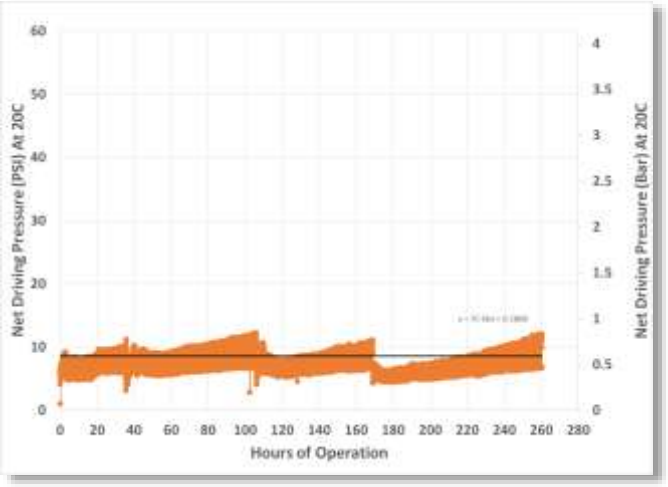


Boise River Study #2: Flux Step Up

1mg/L PACL Coagulant @ 115GFD (195LMH) >96% recovery.
Dead end flow with backwash every 20 mins
Feed turbidity 3-10 NTU. Permeate turbidity < 0.08 NTU
Backwash: 200-230 GFD (340-400LMH) Flux (1.7-2.0X). 10Sec BW+40Sec Flush
mCIP Every ~ 2-3 Days
Average Temperature: 49F (9C)



Before Optimized Maintenance CIP



After Optimized Maintenance CIP

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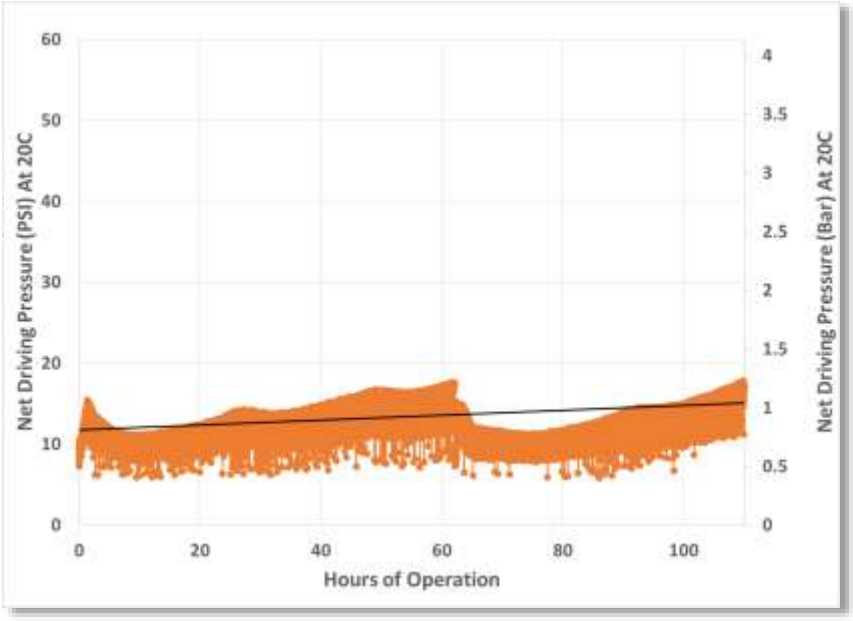
Boise River Study #2: Flux Step Up

2mg/L PACL Coagulant @ 184GFD (313LMH) >95% recovery
Dead end flow with backwash every 15 mins.
Feed turbidity ~3 NTU. Permeate turbidity < 0.08 NTU
Backwash: 368 GFD (626LMH) Flux (2X) 15Sec BW+15Sec Flush
mCIP Every ~ 2-3 Days
Average Temperature: 45F (7C)



Normalized to 20C

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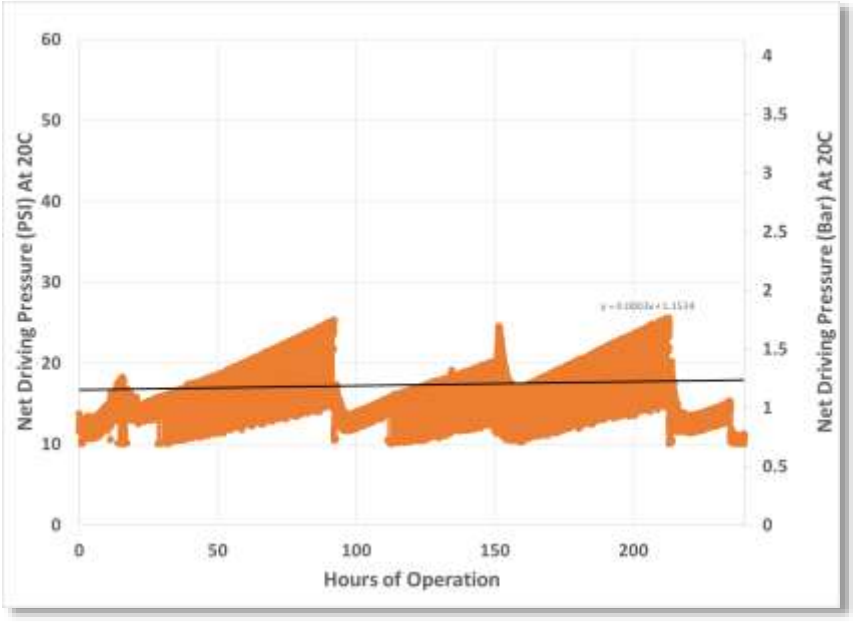
Direct River Water Case Study

5mg/L PACL Coagulant @ 230GFD (391LMH) >95% recovery
Dead end flow with backwash every 15 mins
Feed turbidity ~3 NTU. Permeate turbidity < 0.08 NTU
Backwash: 460 GFD (782LMH) Flux (2X) 15Sec BW+20Sec Flush
mCIP every ~ 3 Days
Average Temperature: 54F (12C)



Normalized to 20C

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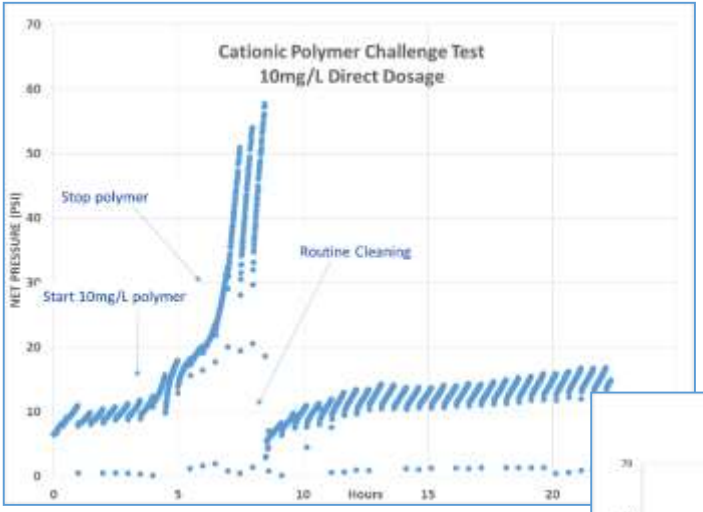
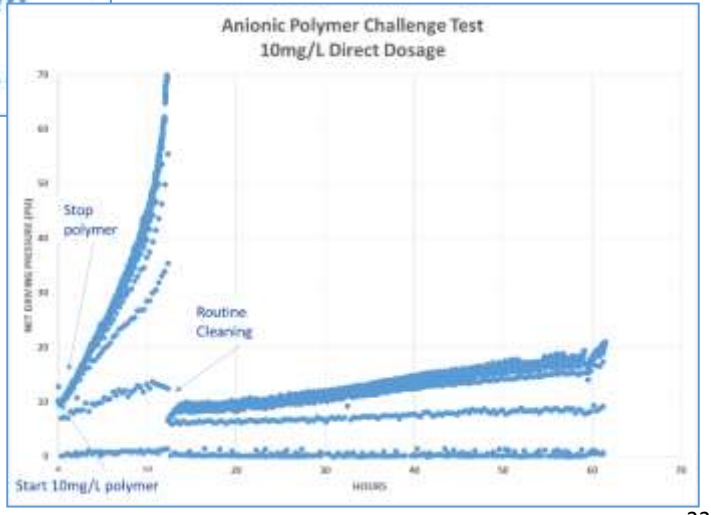
Polymer Challenge Case Study



- Direct injection of 10mg/L of cationic and anionic polymer into feed stream of CM test module.
- Routine CIP of high pH and low pH recovered permeability



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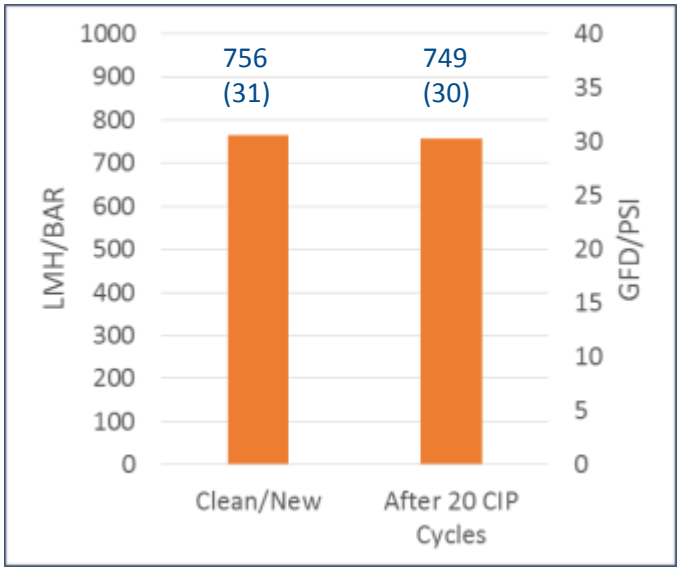
Permeability Consistency Case Study



Module Operating History

- 300 hours of operation
- 20 CIP cycles
- 2 exposure tests of 10 mg/L cationic polymer.

CIP cycles:

- 16 Cycles of 5+mg/L ozone & 300 mg/L hypochlorite rinse
- 4 Cycles of 300 mg/L Hypochlorite plus NaOH to pH 12 followed by HCl to pH 2

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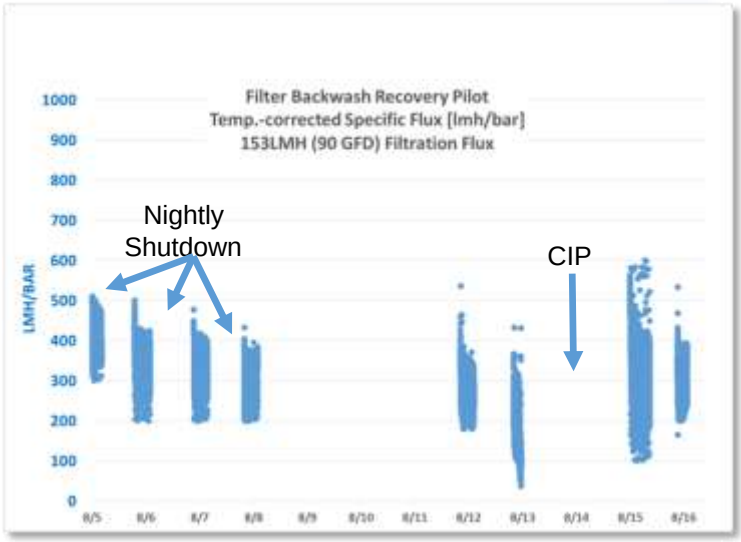
Filter Backwash/Water Recovery Case Study



- 90GFD (153LMH) flux stable in dead-end
- Average 7 psi net driving pressure (0.4bar)
- ~90% recovery
- Effective cleaning NaOCl + NaOH (pH 12) followed by Citric Acid + HCl (pH 2)

- Conventional treatment plant: Coagulation (alum) and filtration (carbon/sand)
- Feed turbidity 50-300 FNU typical; Spikes > 1000 FNU (average 100 FNU); Filtrate always < 0.1 FNU

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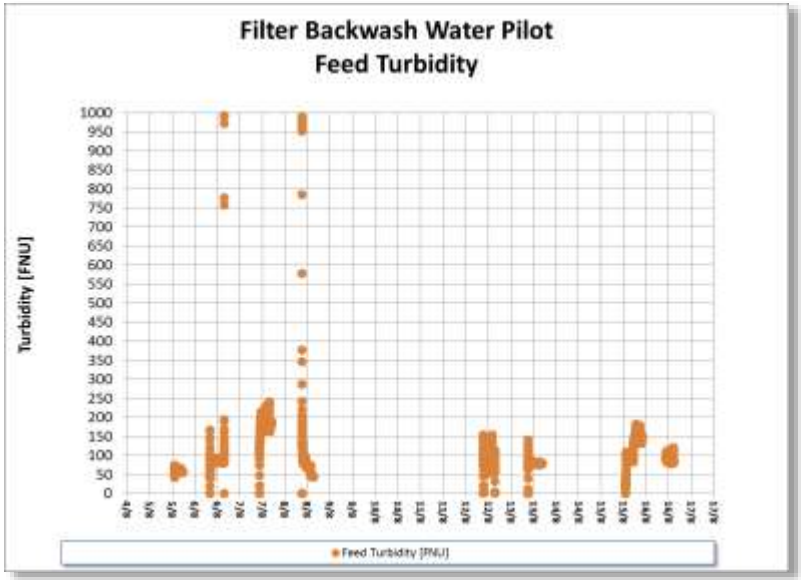
Filter Backwash/Water Recovery Case Study



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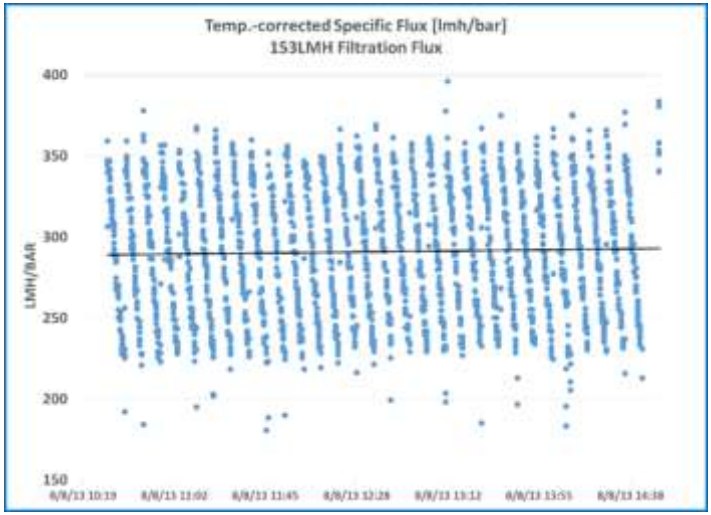
Filter Backwash/Water Recovery Case Study



- 90GFD (153LMH) flux stable in dead-end
- Average 7 psi net driving pressure (0.4bar)
- ~90% recovery
- Effective cleaning NaOCl + NaOH (pH 12) followed by Citric Acid + HCl (pH 2)

- Backwash sequence was with water pump at 800lmh flux for 16 second duration.
- Filtration time changed depending on feed turbidity levels between 4 and 30 min cycles resulting in volumetric recovery rates of 75-95%. Typical filtration time was 12-15 minutes (~90% recovery).

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Ceramic Membranes

- Competitive Initial Capital Cost For Industrial / Drinking Water / Reuse Systems
- Longer Life Span Than Polymeric UF/MF
- No Fibers To Repair
- Wider Range Of Operating Conditions (More Robust)

Special Thanks To
Suez Boise Operations

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