February 20-23, 2023
Knoxville, TN

2023
Membrane Technology
CONFERENCE & EXPOSITION

AMTA
American Membrane Technology Association

American Water Works Association

2023 Membrane Technology
CONFERENCE & EXPOSITION

Field Validation, Technical and Economic Performance for a New Pressure-Driven SiC Ceramic UF for Drinking Water Production

Wednesday, February 22, 2023
10:30-11:00

Winnie Shih
Crosstek Membrane Technology

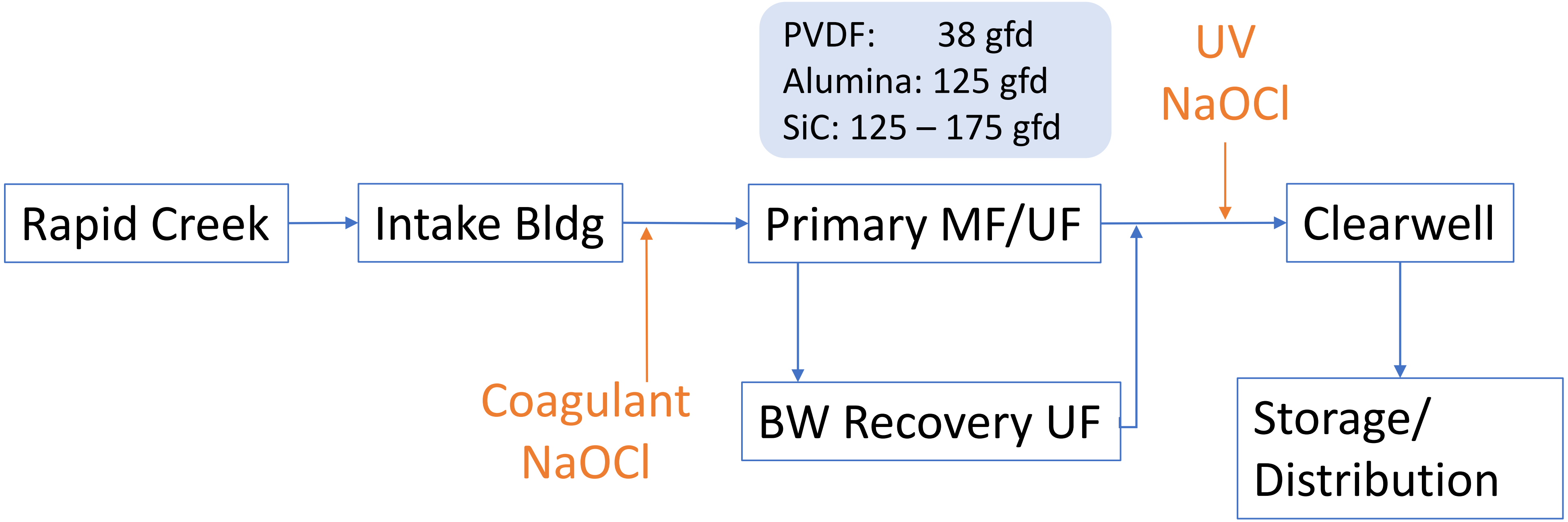
Rapid Valley Sanitary District-Water Service

CROSSTEK

Pilot Objectives

1. Study duration: January 2022 – November 2022
2. Full size Crosstek Ultressa® ceramic SiC pressure membrane (CPM)
3. Source water: South Dakota surface water with inline coagulation/flocculation
4. Side by side existing installed ceramic UF system and leading PVDF hollow fiber membranes system
5. Goals:
   a. Measure performance with different feed coagulants for various flux rates
   b. Compare alum, ACH, Polymer+ ACH blend
   c. Perform integrity testing
   d. Compare with onsite ceramic UF pressure modules
   e. Study temperature / seasonal impacts

Process Flow Diagram



Primary MF/UF: Typical Intake Raw Water Quality:

- Average turbidity: 3-7 NTU (up to 20 NTU)
- TOC: 1 – 6 mg/L
- Fe: 0.3 – 1.0 mg/L typical
- Hardness: 340 mg/L as $CaCO_3$

Pilot SiC Module at RVSD

Membrane Characteristics

Membrane Specifications	PVDF	Alumina	SiC
Pore Size (micron)	0.1	0.03	0.04
Contact Angle (°)	82-92	28-30	17-18
IEP	-	9	4.3
Single Module Membrane Area (ft^2)	538	261	244[a]
Operation	Mild Crossflow	Dead-End	Dead-End
Nominal Flux (gfd)	38	125	[b]125-175[c]

Note:

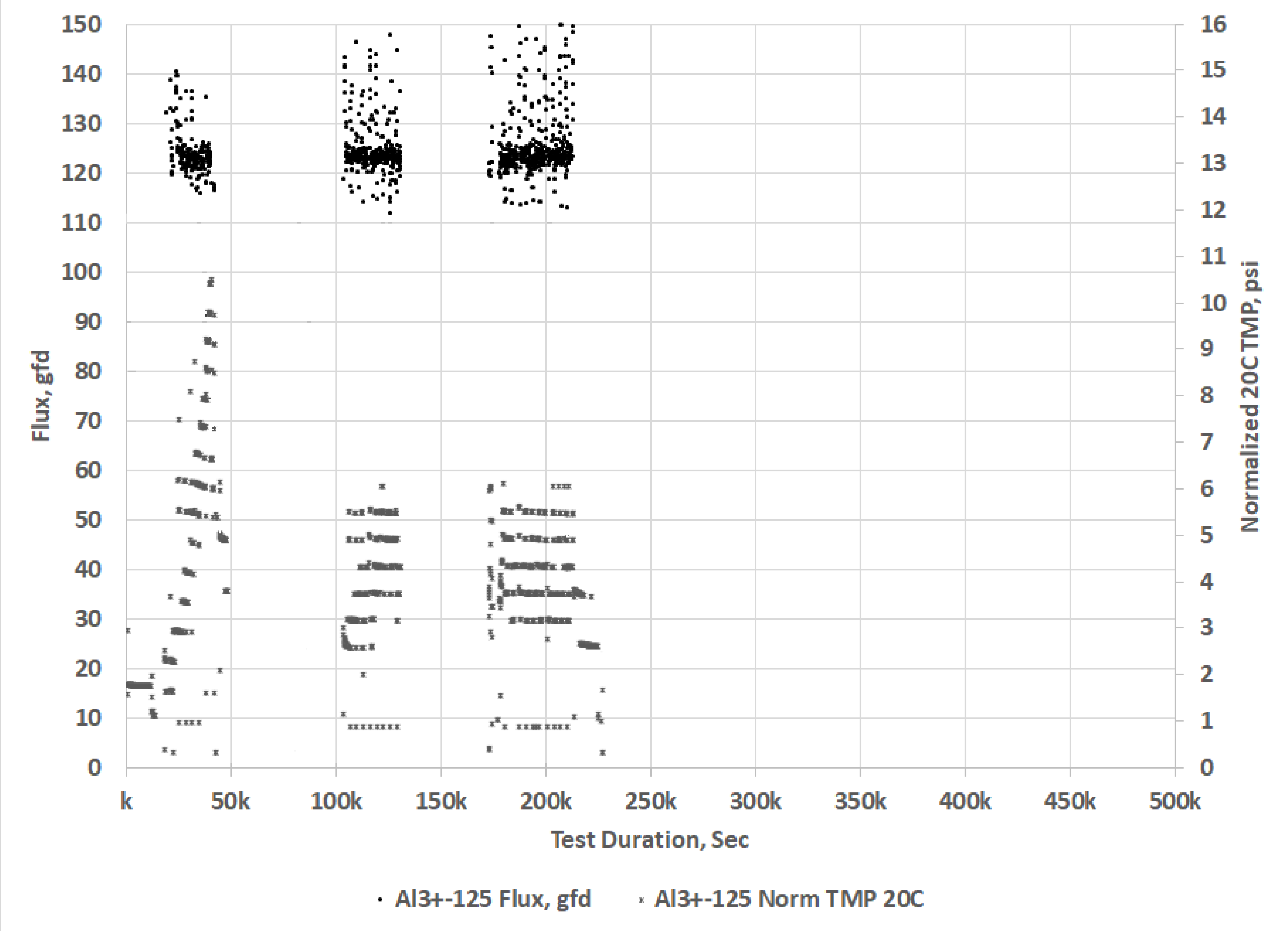
(a) Commercial module optimized to 269 ft^2

(b) Baseline pilot flux : 125 gfd, 30-40 min production cycle, 40 gpm BW flowrate

(c) Max piloted flux: 175 gfd, 30 min production cycle, 40-60 gpm BW flowrate

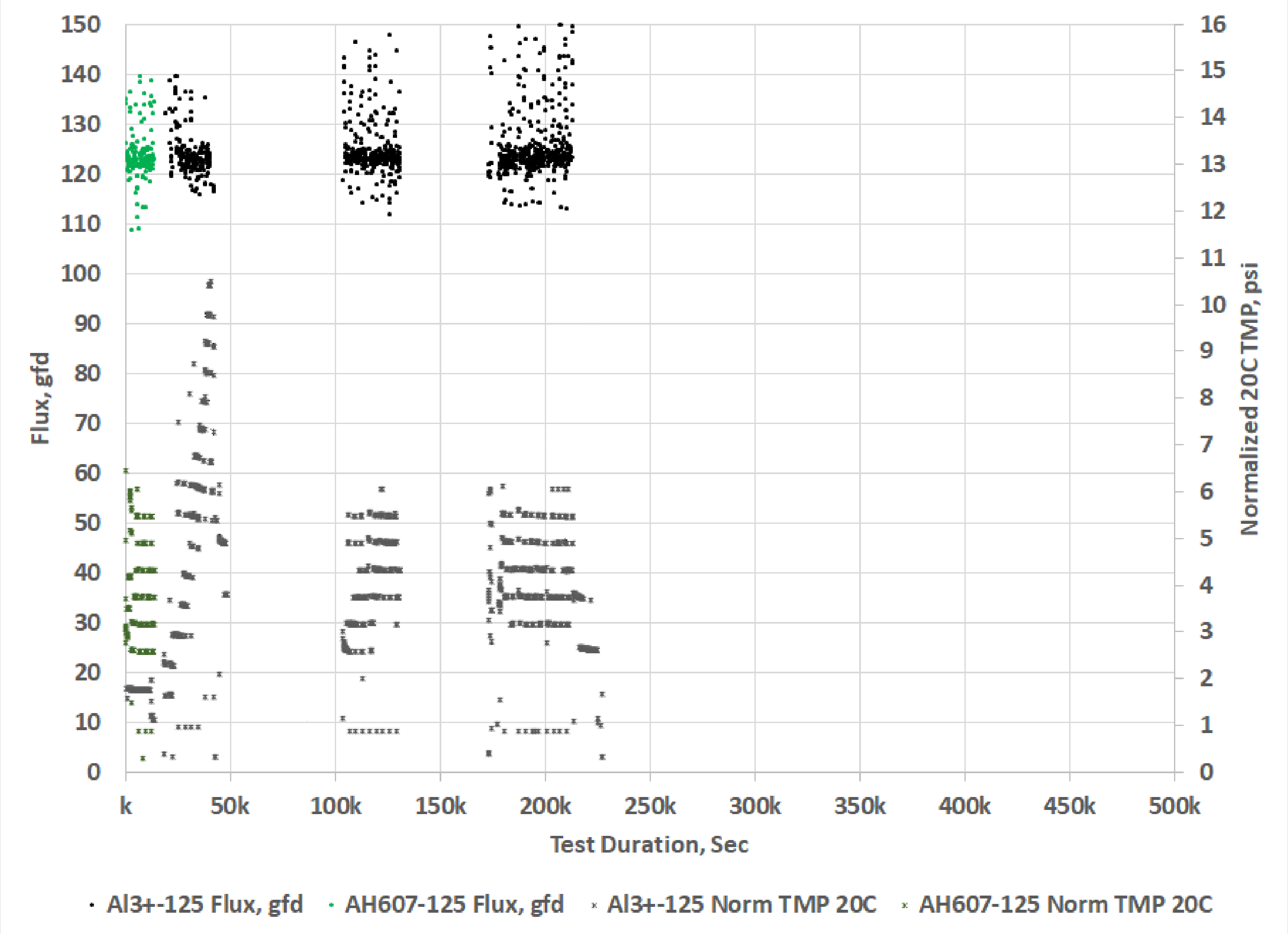
(d) Filtrate turbidity over pilot duration: Jan 2022 – Nov 2022: < 0.1 NTU

125 gfd Baseline Comparison



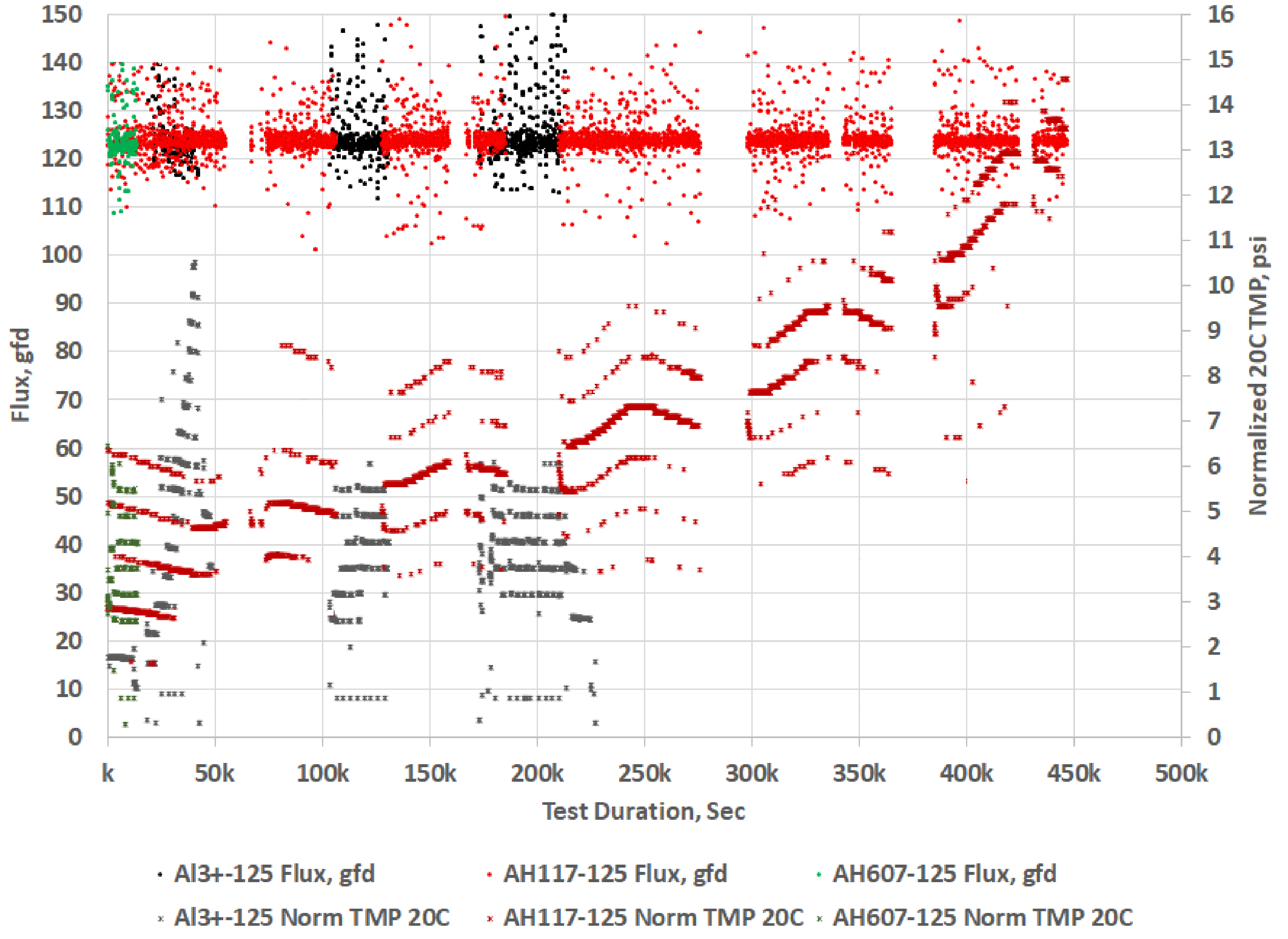
Coagulant	Norm. TMP (psi)
1 mg/L Al^{3+}	3.18 – 4.35

125 gfd Baseline Comparison



Coagulant	Norm. TMP (psi)
1 mg/L Al^{3+}	3.18 – 4.35
13 mg/L ACH	3.16 – 5.47

125 gfd Baseline Comparison



Coagulant	Norm. TMP (psi)
1 mg/L Al^{3+}	3.18 – 4.35
13 mg/L ACH	3.16 – 5.47
13.5 mg/L ACH + 25% Cat Polymer	4.04 – 5.77

Alumina UF @ 125 gfd:

- Norm TMP: 7-8 psi

Lower starting TMP and lower contact angle for SiC UF means SiC UF can operate at higher flux at the same TMP compared to Alumina

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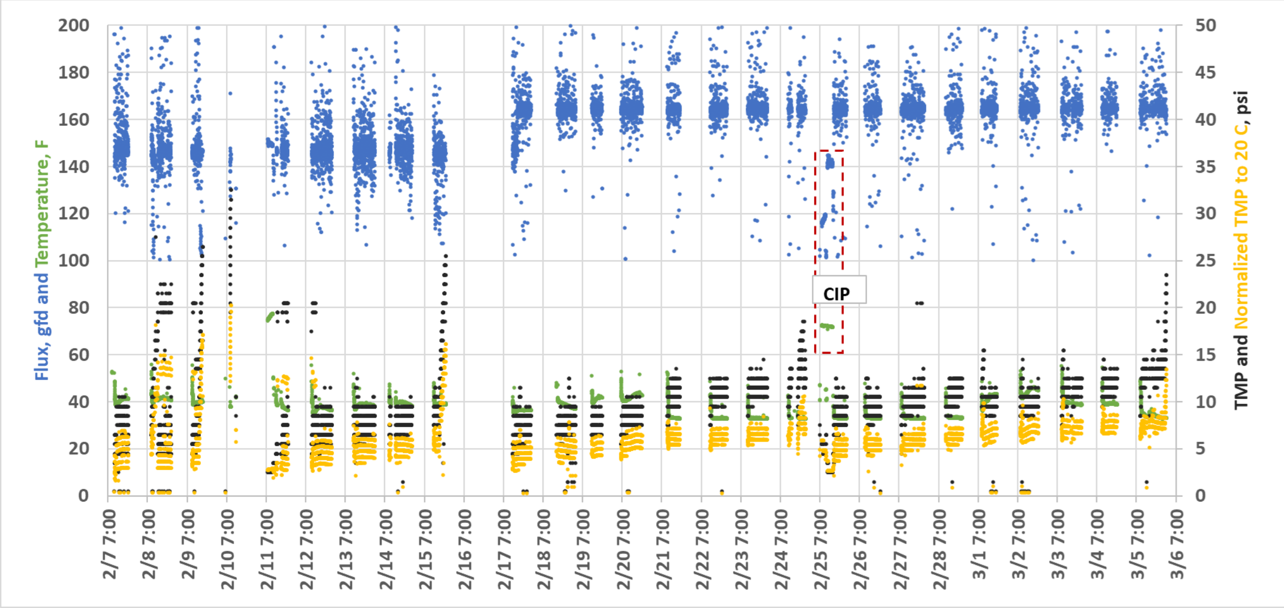
150-165 gfd Flux Stepping (ACH only)

Water Temperature: 34-40 °F

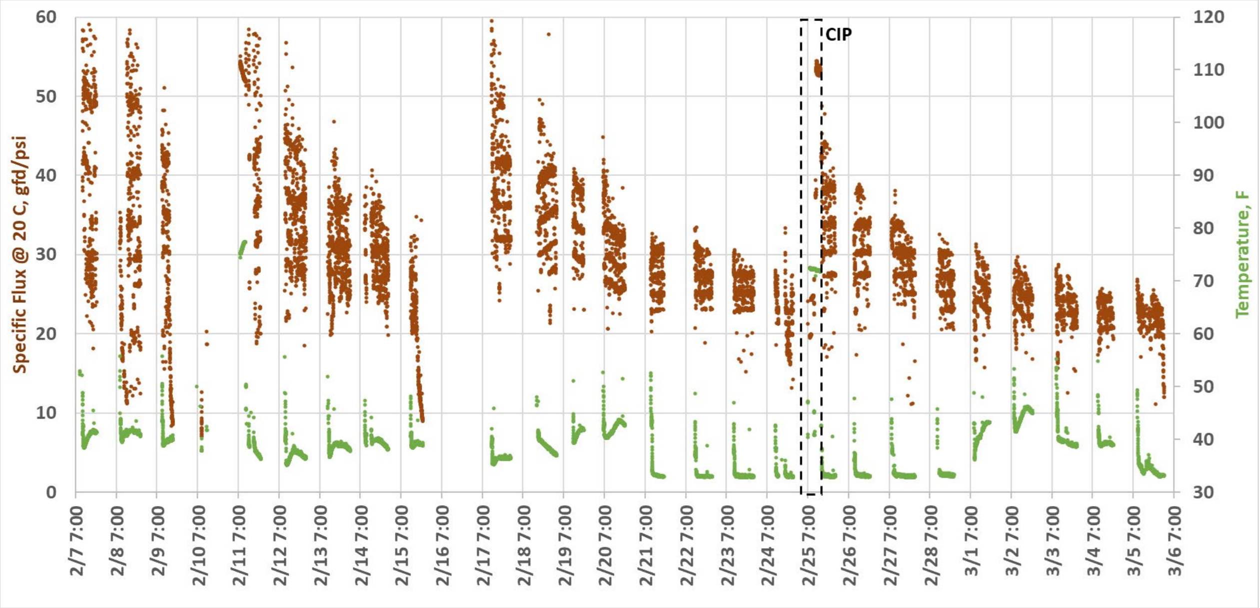
150 gfd: Norm TMP over 5 days: 5 to 7 psi

165 gfd: Norm TMP over 7 days: 4.5 to 13.5 psi

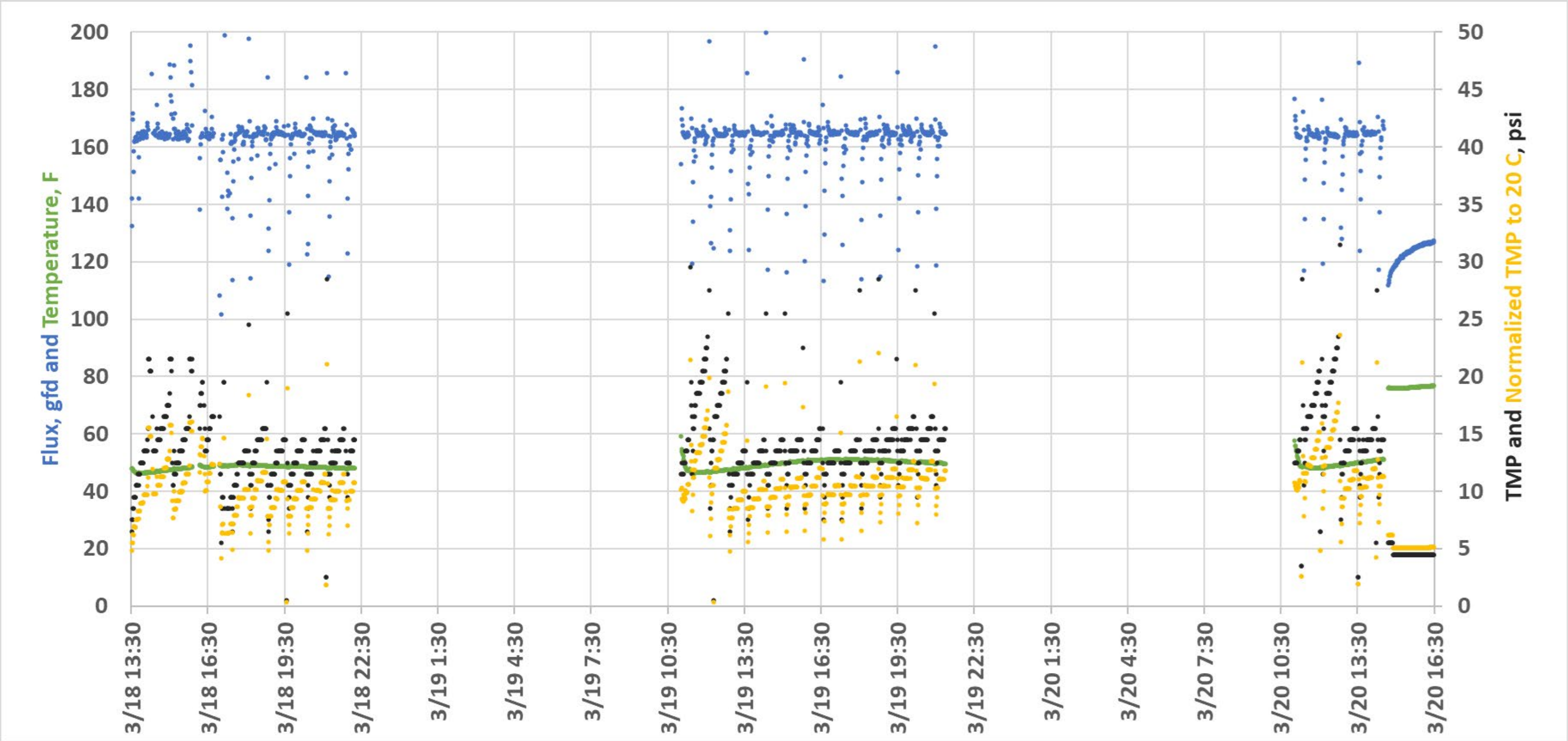


Specific Flux : 45-50 gfd/psi, reproducible

2-step CIP: NaOCl followed by Citric + HCl



Stress Testing with Anionic Polymer + ACH

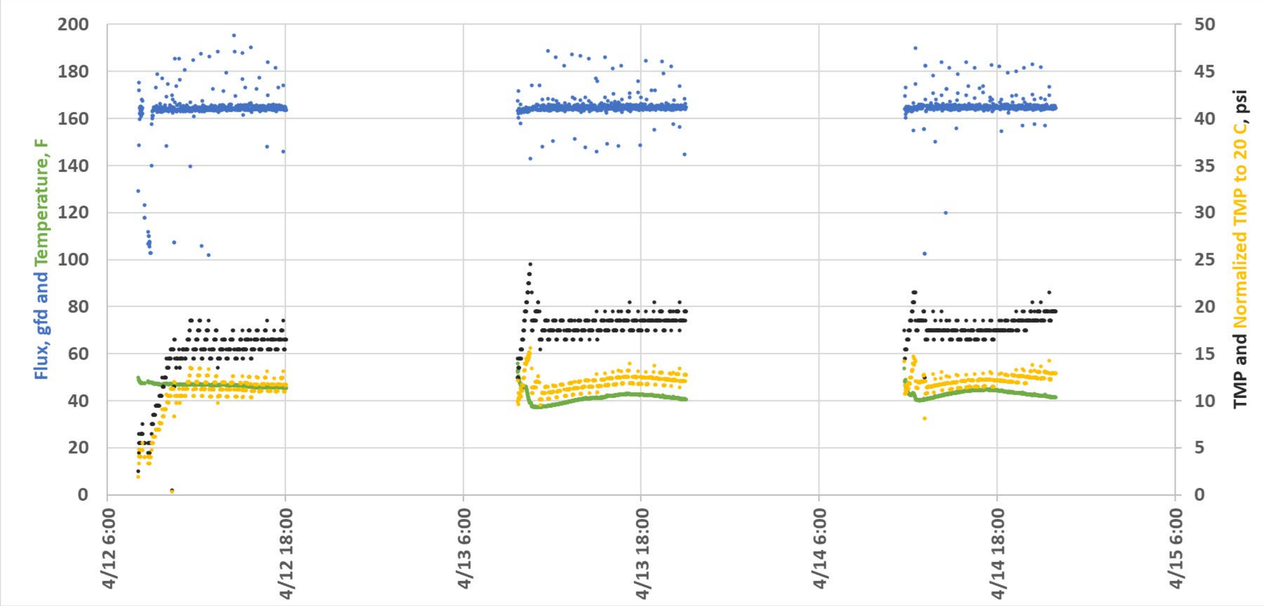


- 0.5 mg/L anionic polymer (flocculant) injected at the intake (2-ft upstream of coagulant dosing)
- Norm TMP rose from 5.5 to 18.5 psi in 1st cycle, and 10.5 to 19.5 psi in 2nd cycle
- BW flowrate increased from 40 gpm to 55 gpm to stabilize the cycle, but unable to lower TMP

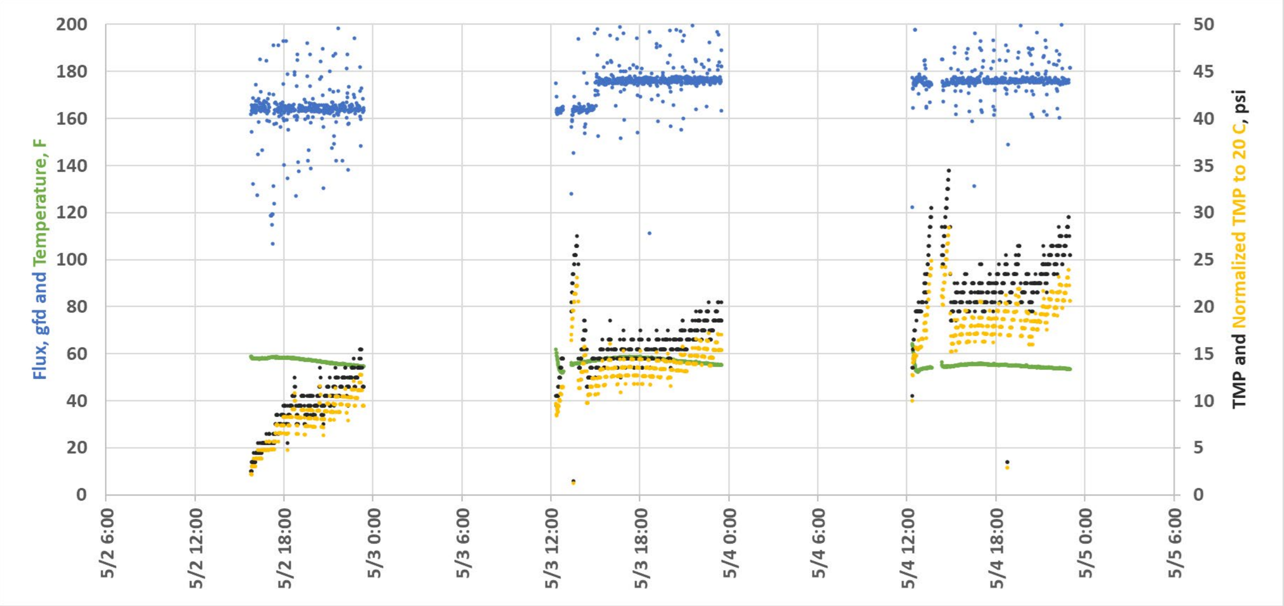
- Extended CIP cycles using NaOCl at pH 9 and Citric Acid + HCl at pH < 2: Less effective
- Final CIP with NaOH at pH 12.5 + low pH clean: recovered starting TMP to 3.5 psi
- Even though SiC is negatively charged, long chain high MW polymers can still foul membrane, but recoverable.

165-175 gfd Flux Stepping (ACH + 25% Cationic Polymer)

165 gfd: Norm TMP: 4.5 to 10 psi in 1st cycle
BW Flux increased from 40 gpm to 60 gpm
Run stabilized at 11-12 psi Normalized TMP

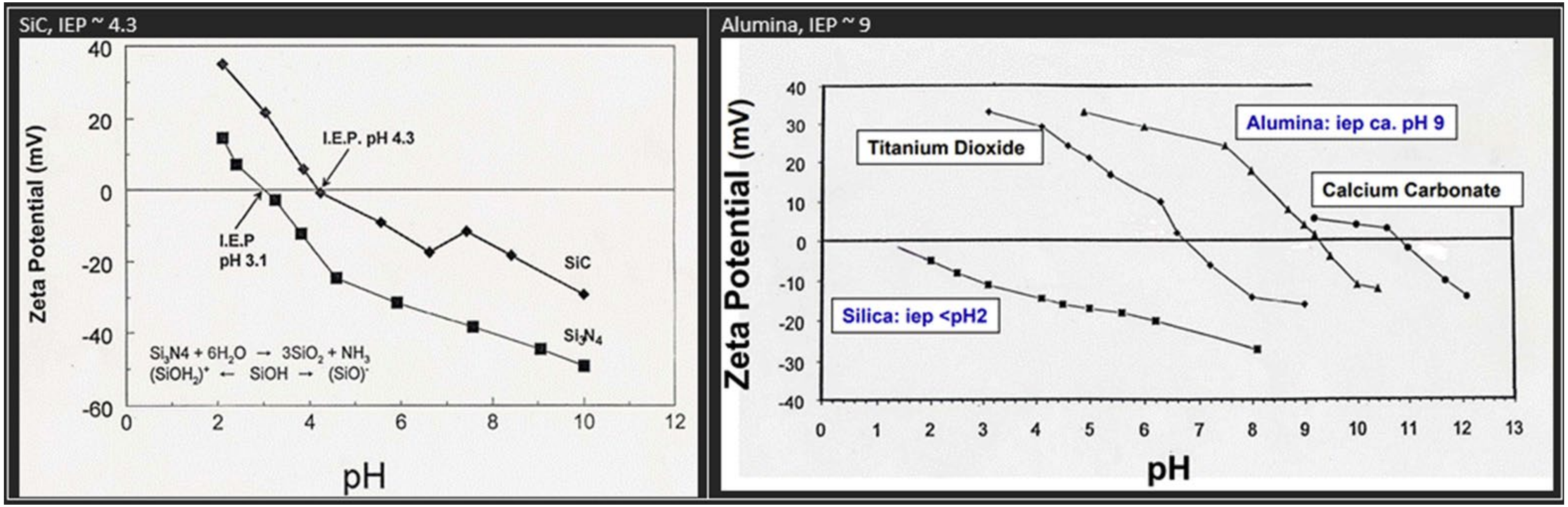


175 gfd:
Norm TMP: Steady increase even at 60 gpm BW



- At 165 gfd, ACH+cationic polymer coagulant blend increased norm. TMP 35-50% over ACH only
- Higher BW flowrate also needed to overcome charge attraction between polymer and membrane surface
- Site reported SiC operated more stably with this blend when TOC is higher

IEP/Surface Charge, and Pre-Treatment



Ideal pre-treatment:

1. Alum or Ferric and no polymer is good for Al_2O_3 and SiC
2. Pre-hydrolyzed coag (ACH, PaCl) is best used at correct dose. Excess will foul Al_2O_3 and SiC. Underdosing worse for Al_2O_3 due to organic fouling
3. If polymer must be used, moderation is vital. Cationic blends workable for both Al_2O_3 and SiC

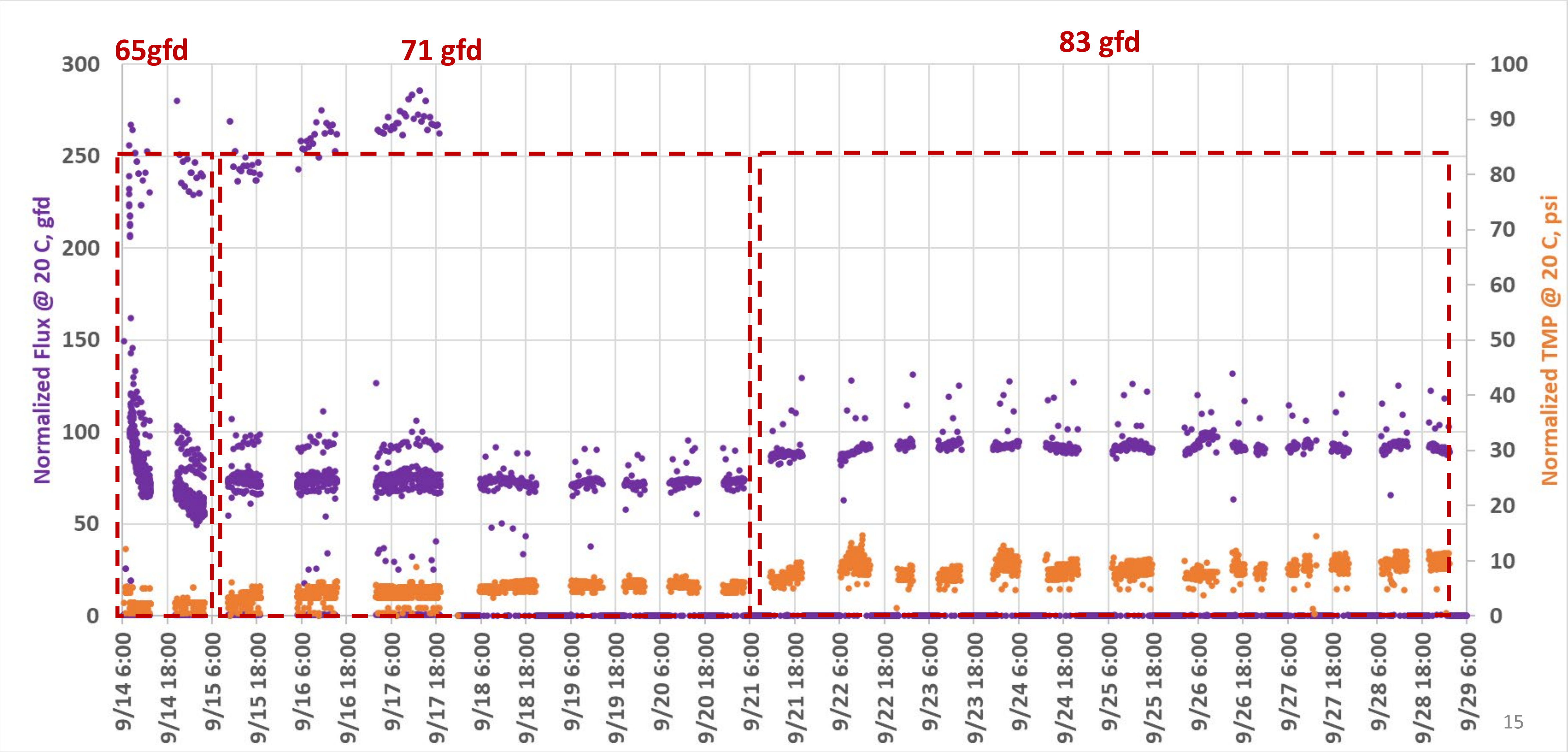
Economic Evaluation: Same membrane count

Membrane	PVDF	Al_2O_3	SiC	
Sewer cost ($/1000 gal)	$ 5.00	$ 5.00	$ 5.00	
Water sale ($/1000 gal)	$ 3.00	$ 3.00	$ 3.00	
Power cost ($/kWh)	$ 0.10	$ 0.10	$ 0.10	
Skid Slots (#)	36	36	36	
24-hr Run Days/ year	300	300	300	Accounting for peak/ave flow
Membrane area (sqft)	537.9	216.4	269.0	
Flux (gfd)	38	125	165	
Membrane Lifetime (yr)	10	20	20	
TMP, avg (psig)	8	8	10	
Pre-treat chem ($/1000 gal)	$ 0.03	$ 0.03	$ 0.03	
Recovery, net/gross (%)	95%	95%	95%	

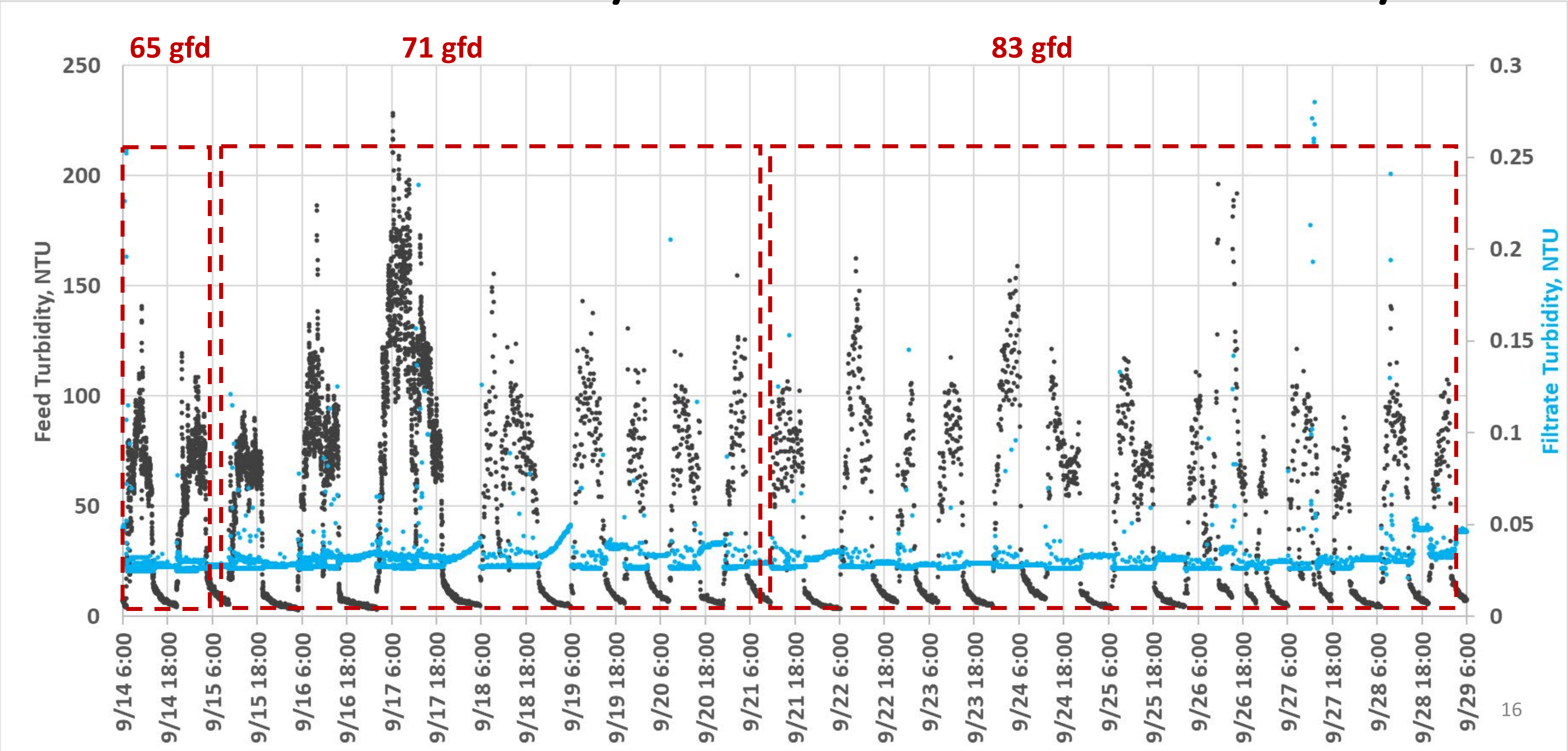
Economic Evaluation: Same membrane count

Membrane	PVDF	Al_2O_3	SiC	
Feed Power ($/1000 gal)	$ 0.01	$ 0.01	$ 0.01	
Total Installed Cost ($)	$ 75,600	$276, 600	$358,028	
Total Installed Cost ($/gpd)	$ 0.11	$ 0.25	$ 0.24	
Water Income ($/yr)	$ 629,173	$ 1,005,848	$ 1,365,967	Water sale
Annual Net Income ($/yr)	$ 566,577	$ 905,746	$ 1,227,081	Minus operating costs
Annual Net Inc over PVDF ($/yr)	$ -	$ 399,189	$ 660, 524	
ROI w/o membrane repl (yr)	Base case (N/A)	0.59	0.43	

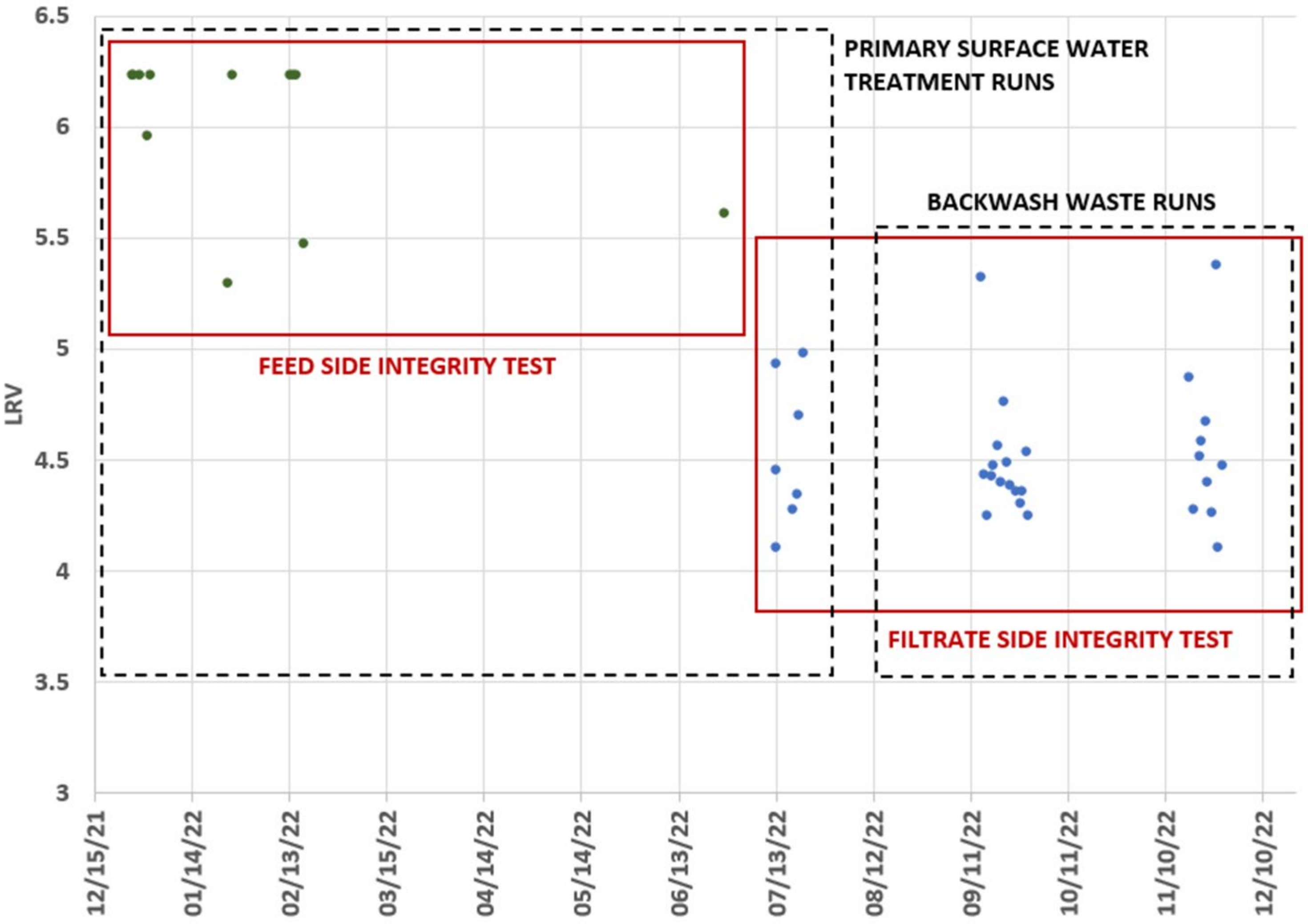
BW Waste Recovery: 30 min cycle, 40 gpm BW Flowrate



BW Waste Recovery: Feed and Filtrate Turbidity



Integrity Test for SiC Module



Membrane Integrity Testing:

- Jan – Mar: Feed Side
- June – Nov: Filtrate Side
    - (piping volume not updated yet)
- LRV > 4
    - Through aggressive BW conditions
    - High TMP stress test conditions
    - Aggressive chemical cleaning at pH 12.5

SiC Pilot Summary

1. Primary Flux was increased at RVSD
   - 38 gfd for PVDF MF Hollow Fiber
   - 125 gfd for Alumina UF Ceramic : Normalized starting TMP 7-8 psi
   - 125 – 165 gfd for SiC UF Ceramic:
2. BW Recovery data shows SiC can perform stably from 65 to 83 gfd at 100+ NTU feed turbidities
   - Incumbent Alumina operates at 70 gfd
   - Permeability 15-20 gfd/psi, similar to incumbent. No advantage for SiC during cake filtration for TSS
3. SiC pressure decay rates were below 0.04 psid/min
4. Preferred pretreatment chemistry: Alum
   - But ACH and ACH + Cationic Polymer formulations can still work
   - For SiC, underdosing coagulant for organic removal is less of an issue
5. SiC compares favorably with Alumina for retrofit projects
   - 50% more production achieved

NSF-419 Approval for SiC Module Obtained in 2022

Ultressa CPM Module Datasheet

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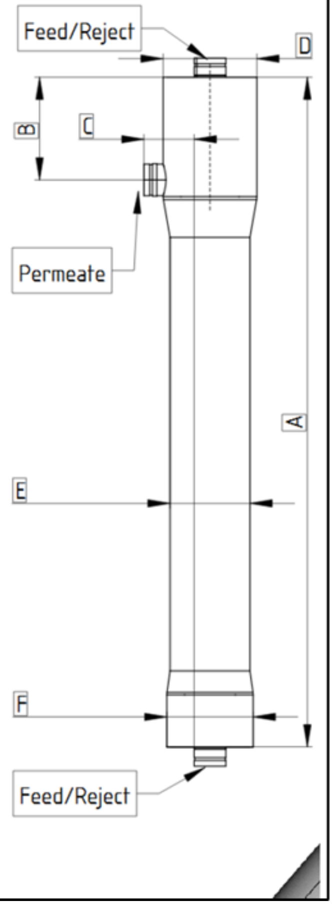
Physical Dimensions

Membrane Module			Ultressa CPM Module	
Module Length	(+/- 4 mm)	A	1899 mm	74.76 in
Side Port Dimension	(+/- 4 mm)	B	297 mm	11.69 in
	(+/- 1 mm)	C	163 mm	6.42 in
Module Diameter	(+/- 4 mm)	D	250 mm	9.84 in
	(+/- 2 mm)	E	216.8 mm	8.54 in
	(+/- 3 mm)	F	245 mm	9.65 in
Grooved Fitting Feed/Reject (Qty 2)			DN-80	3 in
Grooved Fitting Permeate			DN-80	3 in

Specifications

Surface Area		25 m^2	269 ft^2
Nominal Channel Size		2.4 mm	0.09 in
Weight (+/- 5 kg)	Dry	78 kg	172 lbs.
	As Shipped	80 kg	176 lbs.
Module Hold Up Volume		32 L	8.5 gal
Vessel Material		Fiberglass	
		Ethylene-propylene rubber (EPDM) seal with fiberglass ports	
		Outlet end port, Thermoplastic end cap	
Membrane Material		SiC	
Membrane material Pore Size		40 nm	
Module Operating Position		Vertical	



Form factor allows direct replacement for retrofitting exiting hollow fiber membrane skids

CERTIFICATE OF COMPLIANCE

Certificate Number MH65397
Report Reference MH65397-20211201
Date 2021-December-07

This is to certify that representative samples of the product as specified on this certificate were tested according to the current UL requirements

Trade Designation
USC, CNC
"Ultressa® CPM"

Standard(s):
NSF/ANSI/CAN 61–2019, Drinking Water System Components - Health Effects

NSF

Certified to
NSF / ANSI 61

Bruce Mahrenholz, Director North American Certification Program

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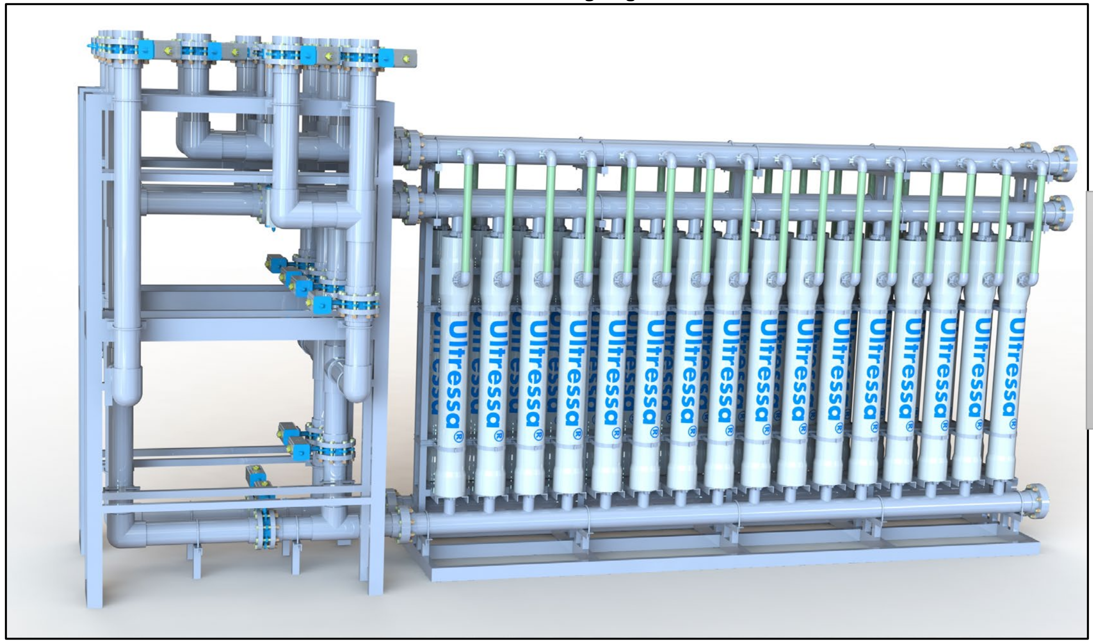
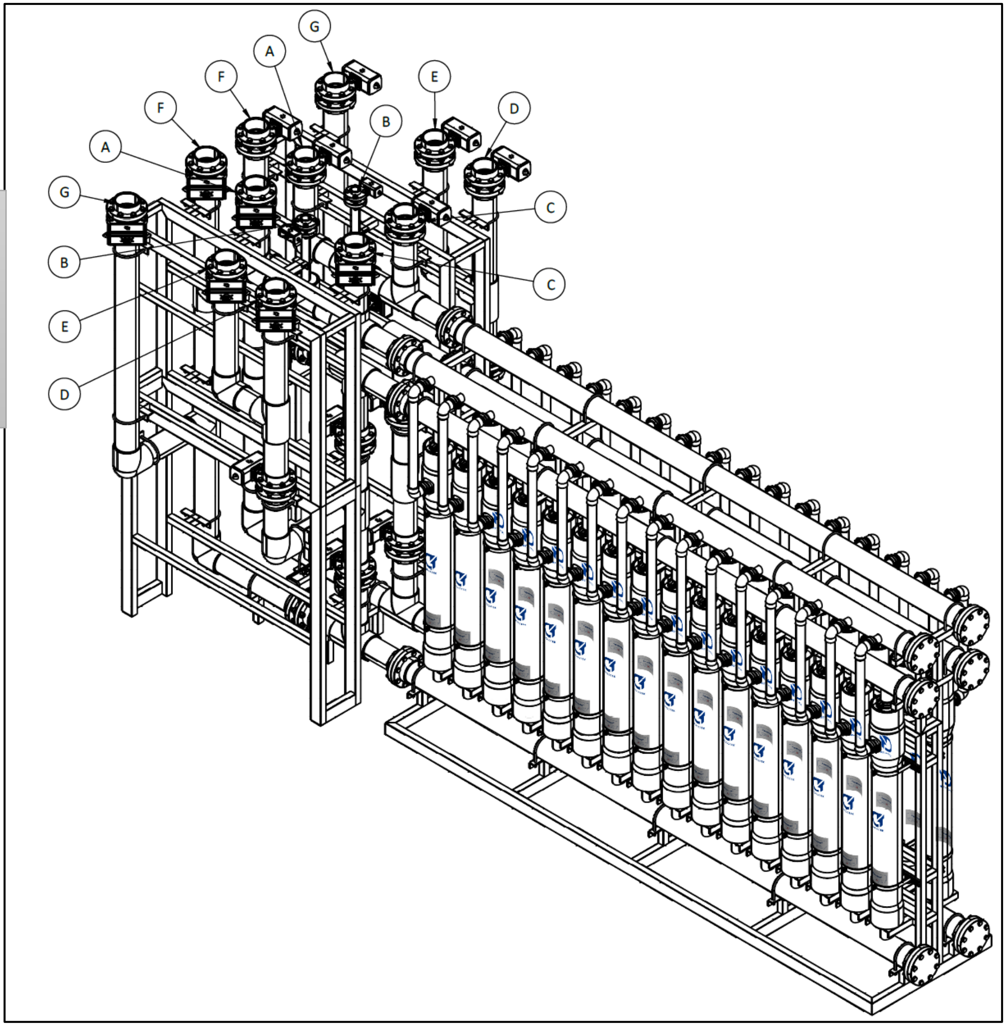
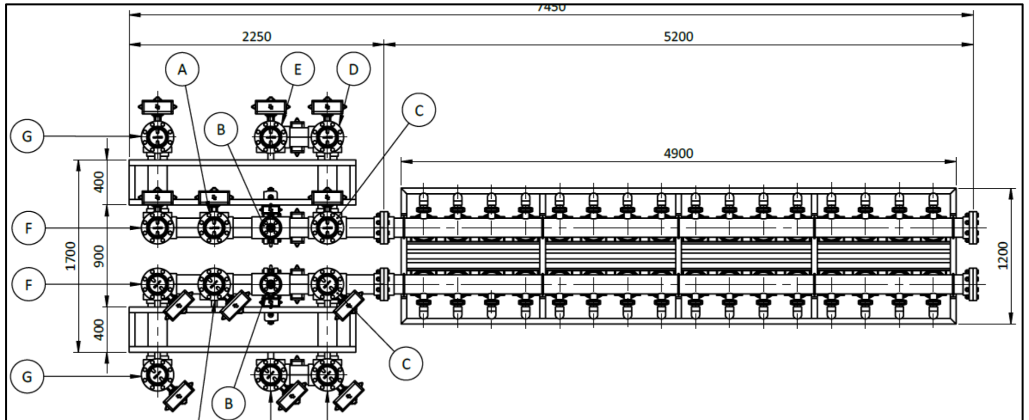
SiC CPM Typical Skid Configuration



CPM form factor allows direct replacement for retrofitting exiting hollow fiber membrane skids





Top View

Acknowledgements

- Pilot and Project Team:
  - Rapid Valley Sanitary District
    - Rusty Schmidt, General Manager
    - Dave Flint, Field Op. Supervisor
  - Vessco, Inc
    - Steve Roberts
  - Crosstek Membrane Technology
    - Stanton Smith, Julian Arroyo

Thank you. Any questions?

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