2022 Membrane Technology CONFERENCE & EXPOSITION
AMTA American Membrane Technology Association
American Water Works Association

Retrofit of Hollow Fiber MBR with Submerged Ceramic Membranes for Fats, Oils and Hydrocarbon Management in Industrial Reuse Plant

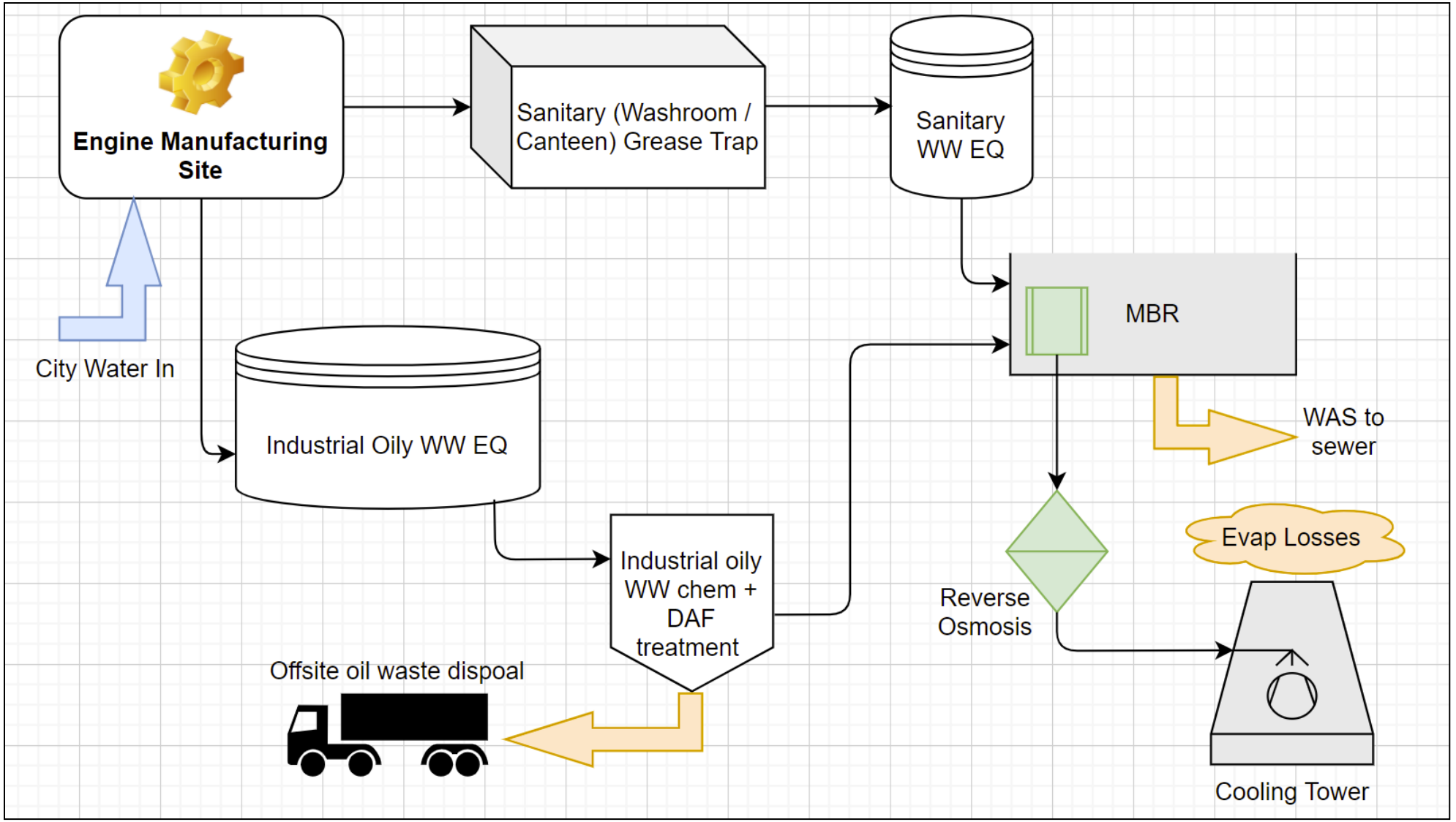
Stanton Smith
Crosstek Membrane Technologies, LLC

CROSSTEK

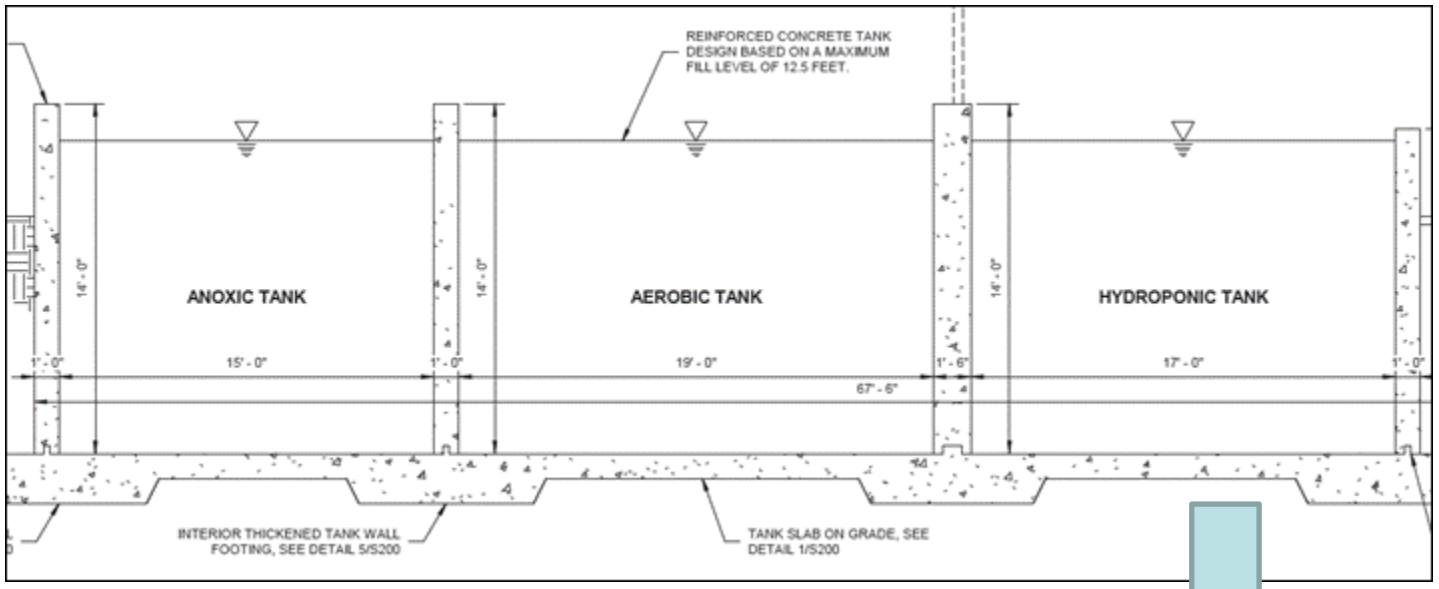
Introduction and Acknowledgements

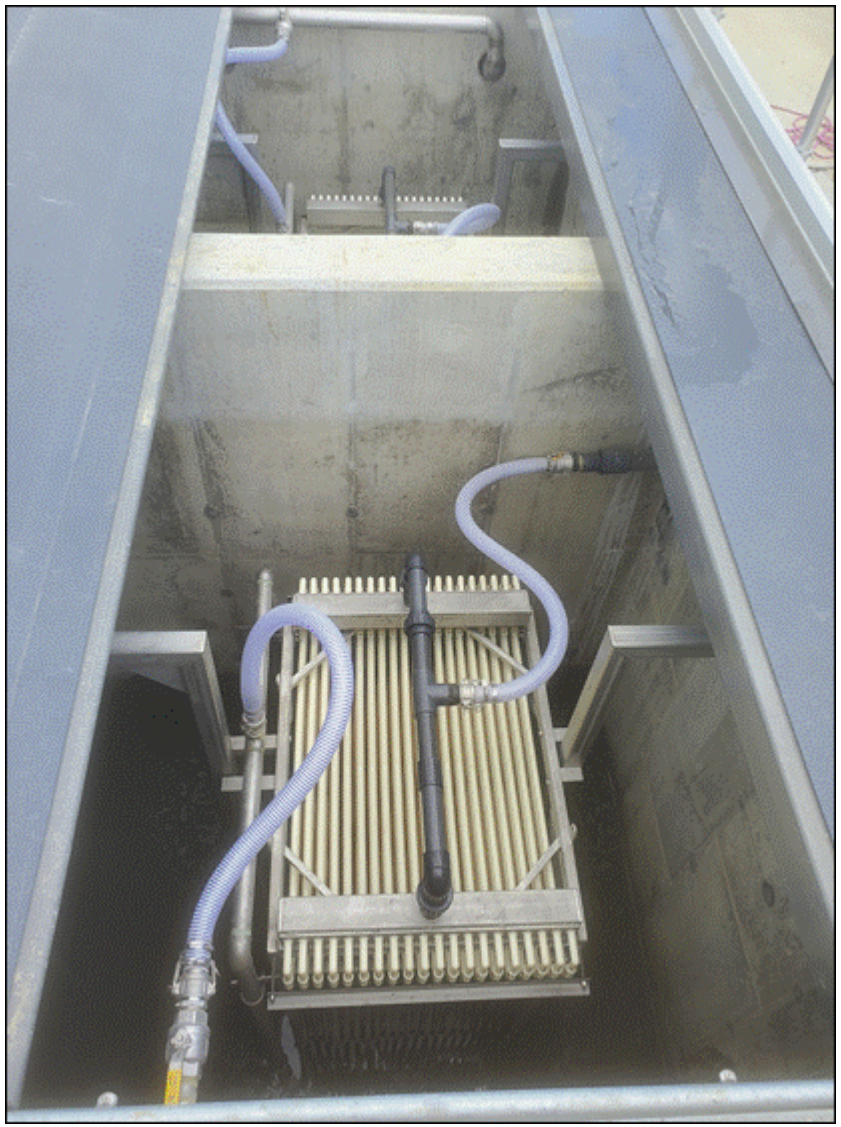
- **Pilot and Project team:**
  - *NextEra/Sustainable Water:* Eric Lohan and contract team
  - *Crosstek:* AbdurRehman Rashid, Hunter Obenschain, Job Omweno, Julian Arroyo
  - *Site/Operations teams*: Utility Partners and Owner staff

Reuse Process Block Flow Diagram



Original MBR Plant Design





- 2 x 50% Membrane Basins
- Total Basin vol. = 181,000 gallons
- HRT (An,Ae) > 2 days

Original MBR Description

- Original MBR seeded mid-2020, with regular MBR operation beginning September 2020
- Used submerged PVDF hollow fiber membranes
- MBR Design Flux ≤ 5 GFD
- Air scour, relaxation and CEB as cleaning methods
- RAS = 6Q RAS. MLSS = 8,000 mg/l (Membrane tank)
- MBR effluent @ RO quality: SDI < 3, BOD < 5; NTU < 1

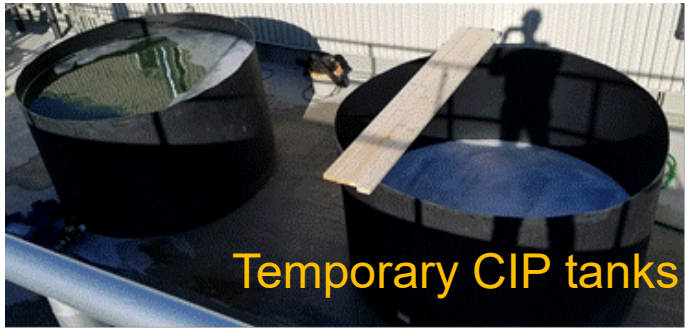
Operational Challenges

- 4 months into operation, MBR started fouling rapidly
- Fats, oils and greases (FOGs) from canteen, and total petroleum hydrocarbons (TPHs) from industrial WW, each were > 100 mg/l in membrane tanks

Historical Feed values				
MBR Tank I		MBR Tank II		
FOG	TPH	FOG	TPH	Date:
110	61	106	52	11/10/2020
190	139	103	58	11/11/2020
343	235	168	107	12/2/2020
119	74	56	51	12/15/2020
130	77	170	121	12/29/2020
194	119	155	96	1/6/2021
323	191	212	145	2/4/2021
273		219	135	2/17/2021
237	122	592	363	2/25/2021
213.2	127.3	197.9	125.3	**Average**
343	235	592	363	**Highest**
110	61	56	51	**Lowest**
81.9	56.6	148.0	90.4	**Std Dev**

Operational Challenges Continued

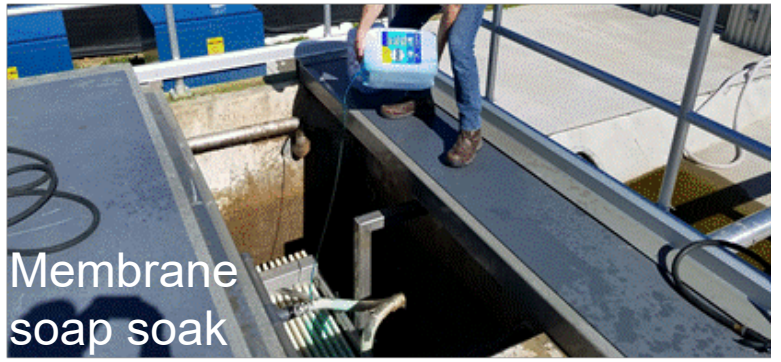
- MBR became unreliable and operationally intensive:
  - frequent production downtime for cleanings
  - cumbersome cleaning: draining / lifting membranes out / soap wash
- Not meeting wastewater reuse flow rate goals


Temporary CIP tanks

Membrane offline cleaning. Operations and HSE did not want this in future


Membrane soap CIP


Membrane extraction


Membrane soap soak

Potential Permanent Solution: Submerged Ceramic Membranes

Challenge	Solution
Ceramic membranes used in oil emulsion splitting due to hydrophilicity BUT operate in crossflow mode	Crossflow for submerged membranes can be introduced by aggressive air scour operation
Project had residual COD > 200 mg/l which could foul alumina ceramics, coating hydrophilicity that could lead to oil emulsion coating and fouling	Silicon carbide ceramic membranes have higher hydrophilicity than alumina (contact angle ~10^{o} less) and preferred negative surface charge repels organics

Pilot Trial (….fool me twice…..)

- 2-month long pilot trial was planned with full-size silicon carbide (SiC) ceramic microfiltration (MF) membrane
- Feed from existing site bioreactor and operating at the same MLSS and RAS rate, but using aeration and cleaning equipment provided with SiC MF pilot plant
- Trial focused on:
  - Maximum re-purposing 1-year old hollow fiber MBR components
  - Proving process reliability

Pilot Trial Preparation

- Key equipment studied for re-purposing:
  - Bio: as is for MLSS, HRT, F:M, coag, DO
  - Air scour blower: underpowered. Motor upsized and re-sheaved for ceramic max ‘crossflow’. Hence eliminated air scour rate as pilot study parameter. New diffusers added
  - Permeate pump: as is - ceramic permeability was higher and pump had full capability for BW / CEB / production and slightly sub-optimized for spray down (rare CIP event)
  - Membrane basins: as is. Ample space. Flow path re-directed to match ceramic membrane geometry

Pilot Trial Preparation (cont'd)

- Key equipment studied for re-purposing:
  - PLC / HMI: as is, similar production / BW / CEB / air scour features, just setpoint changes. Added spray down option
  - Remote PLC/data management: as is
  - Accessibility: as is. Crane remove old and install new membranes
  - RAS: as is. Slightly undersized at peak flow, but above 4Q
  - Piping: as is. Similar flow rates and acceptable line loss

Pilot Test Plan

- With equipment re-purposing design incorporated, the remaining focus of pilot trial was process reliability aspects:
  - Membrane life: five+ year life desired. Difficult to measure in short term pilot but used observation combined with supplier experience
  - Flux stability / permeability at required project normal and peak production rate, assessed at practical cleaning regime:
    - Avoid lifting membranes from basins
    - Use only HSE-approved cleaning methods/chemicals
  - Use constant ‘max’ constant air scour rate
  - Study period was minimum one month to observe production variations
  - Measure fouling rate for range of flux values to set normal and peak flux

Pilot Plant

Pilot setup

Typical Feed

SiC ceramic module

Pilot Results 1: Membrane Lifetime

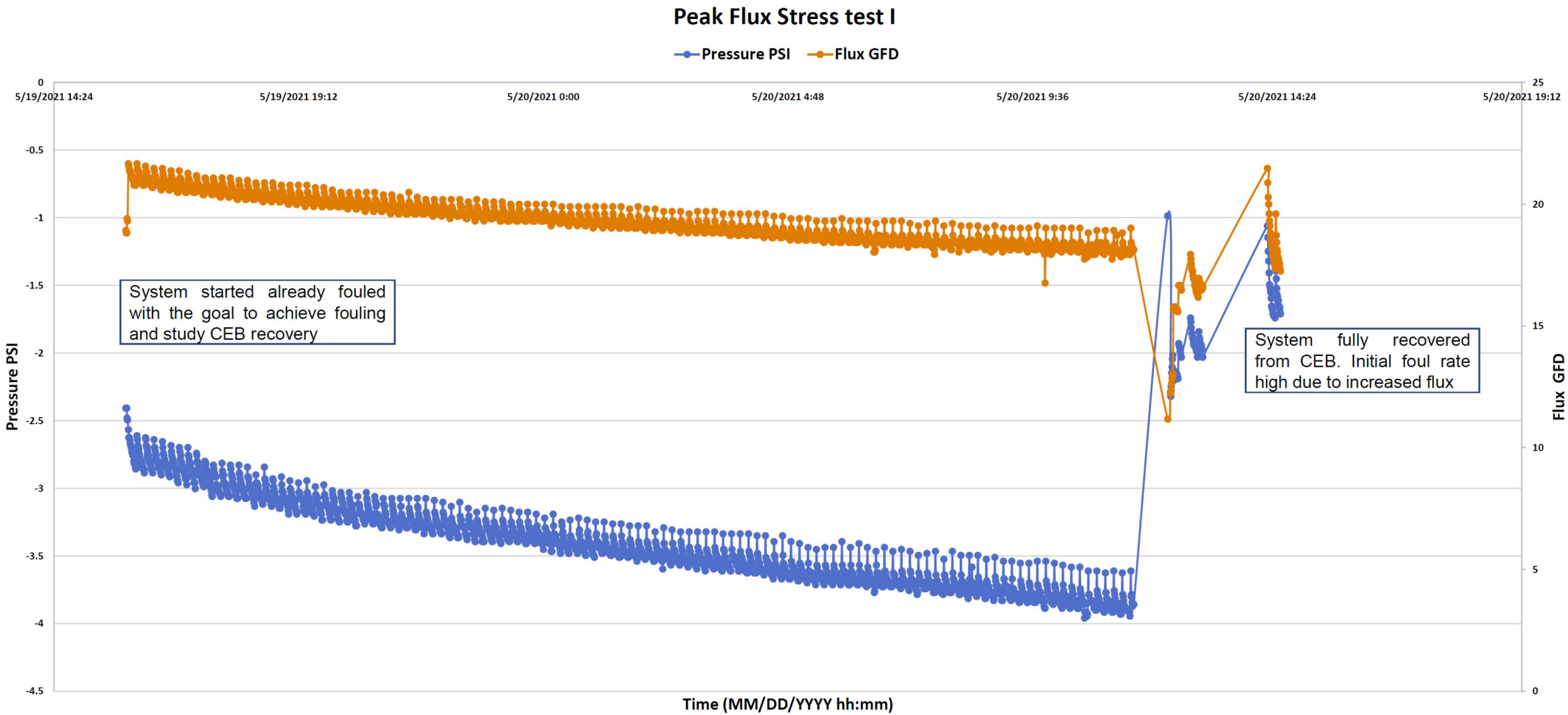
- Ceramic material lifetime expected > 5 years by experience
- Studied plastic/elastomer/adhesive components in pilot for attack by TPH, but no visual attack or softening observed
- No problems in 3 months of run time

Pilot Results 2: Determine Normal Flux

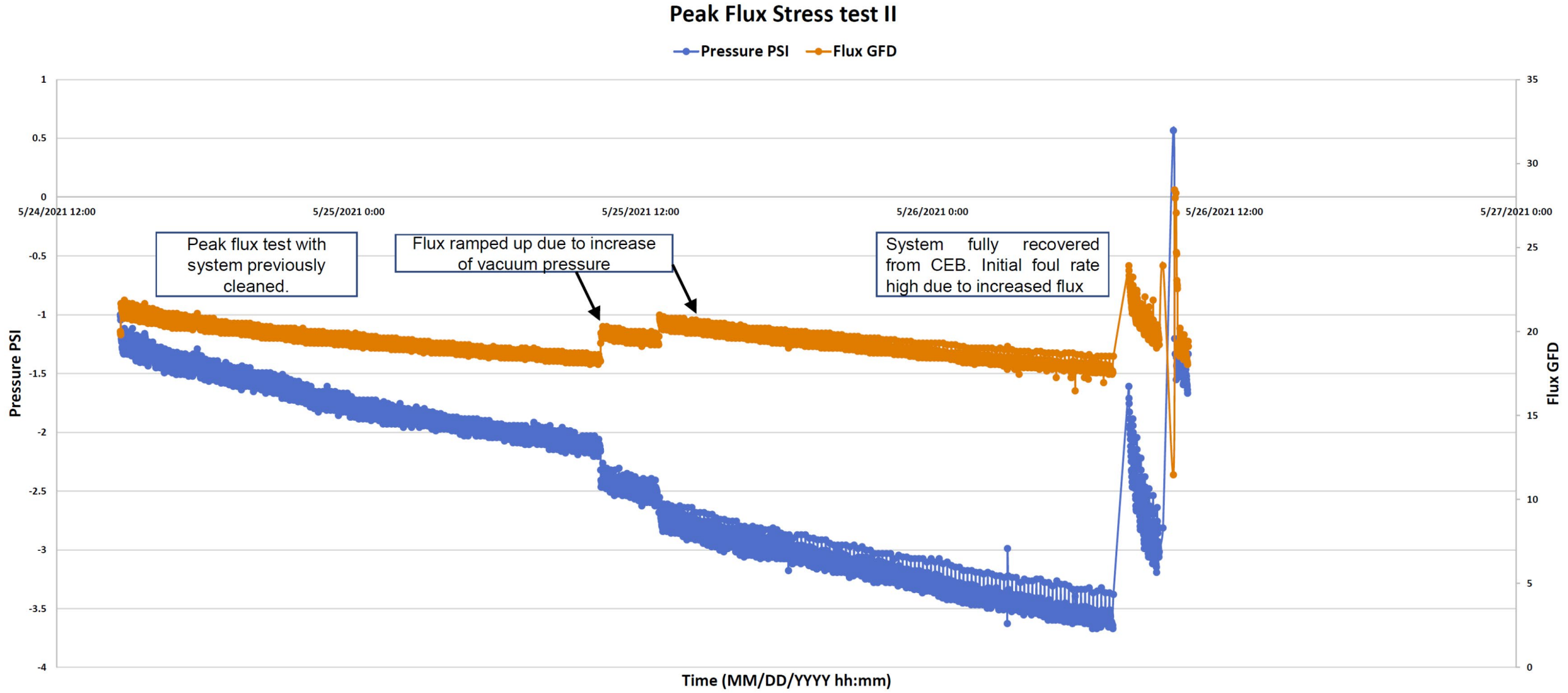
Notes:

1. The initial CEB was at very low TMP. The methodology was as the currently programmed plc, no changes required except concentration of chemicals. 1000ppm NaOCl
2. The fouling at high flux gives around 1- 2 days of operation before CEB.
3. The fouling at average design is very small and the operation will be in the range of 2-4 weeks
4. The feed is more fouling during regular operations hours 4:00 AM to 3:00PM
5. The feed is less fouling outside regular operations hours 3:00 PM to 4:00AM
6. Some of the up two 3/4/2021 4:00 PM are Crosstek setting up the system, and securities.
7. Some event happened around 3/5/2021 5:00 PM

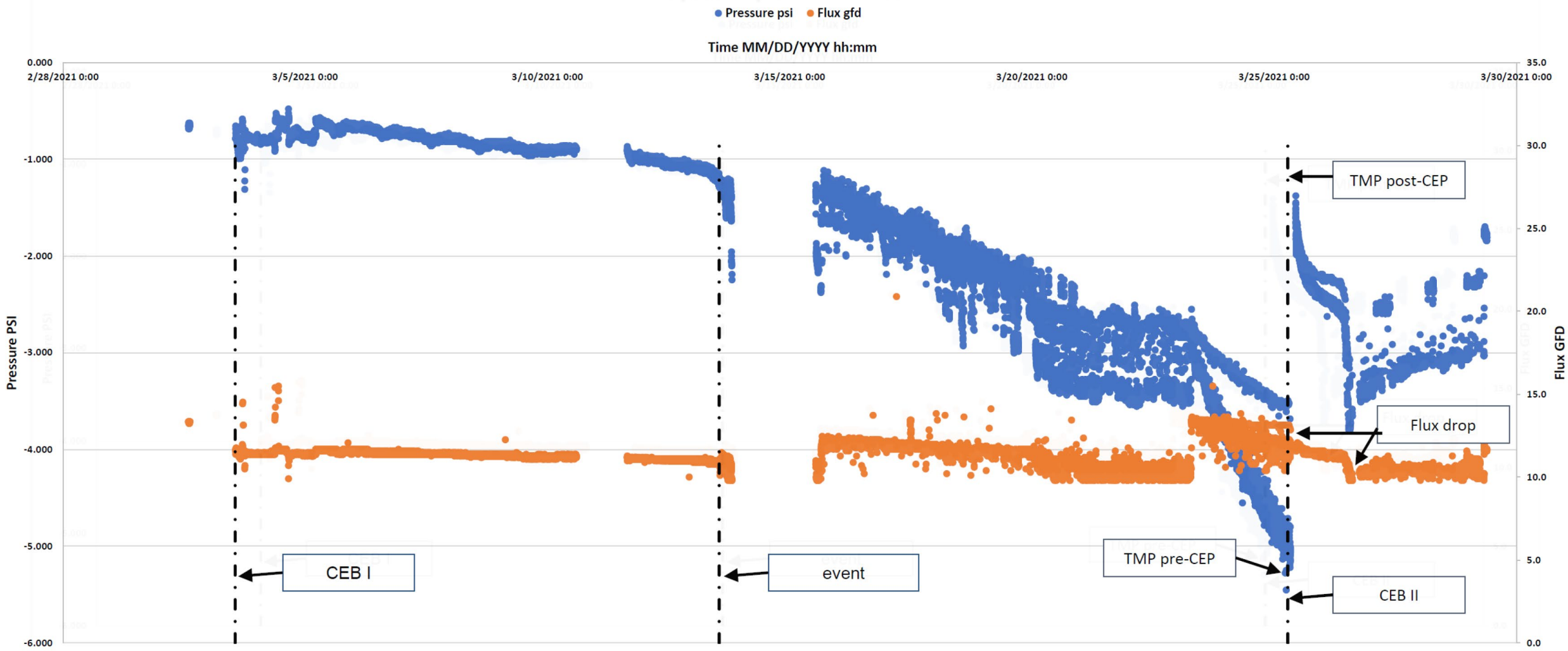
Pilot Results 3a: Determine Peak Flux I



Pilot Results 3b: Determine Peak Flux II



Pilot Results 4: Robustness – Feed Loss Event



Pilot Results 5: Trial Summary and Analytical

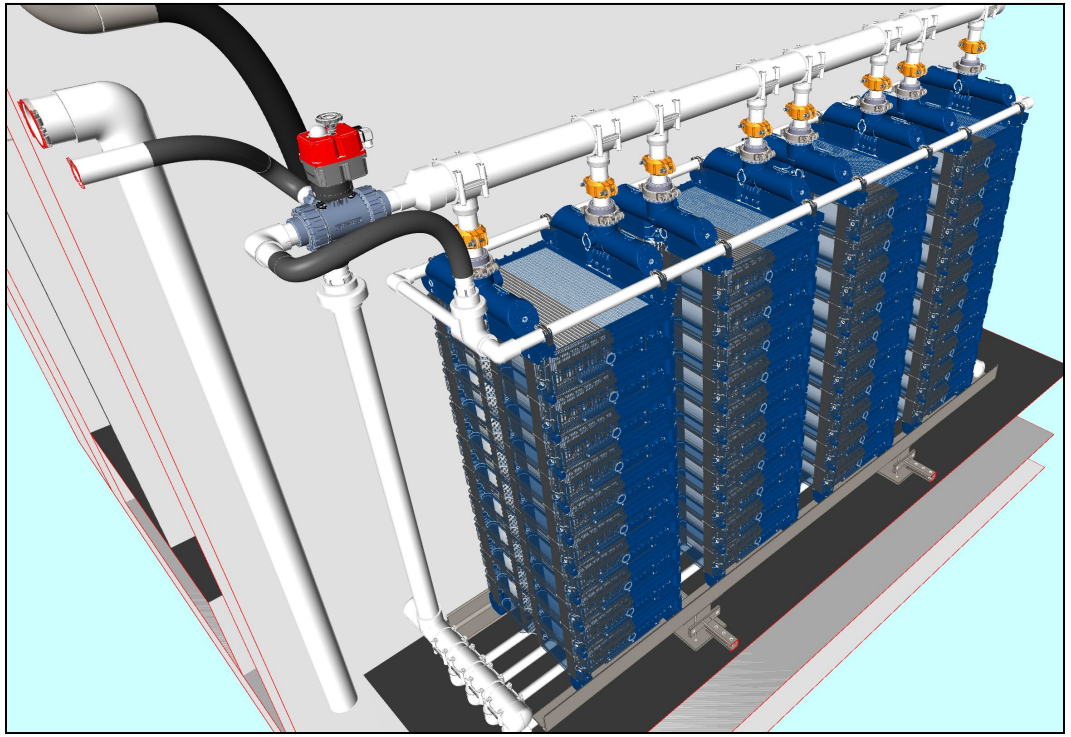
Stream	TSS mg/l	BOD mg/l	COD mg/l	Ammonia mg/l	Iron mg/l	T Phos mg/l	Manganese mg/l
Pilot	<1	<2	176	0.24	0.983	0.871	0.762
Existing	<1	2.8	180	0.34	1.15	0.865	0.79

Stream	Conductivity uS	Turbidity NTU	ORP mV	pH	Temperature F	SDI
Pilot	1072	0.12-0.44	167	6.7-7.3	70	0.7-2.0

Trial #	Run time	Flux (GFD)	CEB (type)	TMP (recovery)
1	14 hours	20	Bleach	99%
2	10 hours	20	Bleach	99%
3	21 days	11.5	Bleach-Acid	99%
4	6 days	17-13	Bleach-Acid	99%
5	2 days	17-15	Bleach-Acid-Caustic	99%
6	40 hours	20	Bleach-Acid-Caustic	99%

Commercial System Design

Design Parameter*	Value
RAS rate	6Q (average); 4Q minimum
Aeration rate per tower (+/-10%)	30 SCFM / 50 Nm3/hr
Backwash flux	1 to 2X versus production flux
Backwash frequency	> 8 min production time
Chemical cleaning frequency	Estimated 1 per week
Cleaning chemicals, nominal concentration	NaOCl 0.2 to 0.5wt% Citric acid 1 to 2wt% Hydrex / Opticlean B 1wt% pH 11.5-12
Number of towers per train / no. trains	4 / 2
Ave / Peak Permeate Flux (Filtrate)	8.4 / 14.5 GFD
Number of modules per tower	10
MLSS (membrane tank / RAS)	6,000 - 12,000 mg/l
TPH (membrane tank / RAS)	61 – 235 mg/l
FOG (membrane tank / RAS)	56 – 592 mg/l



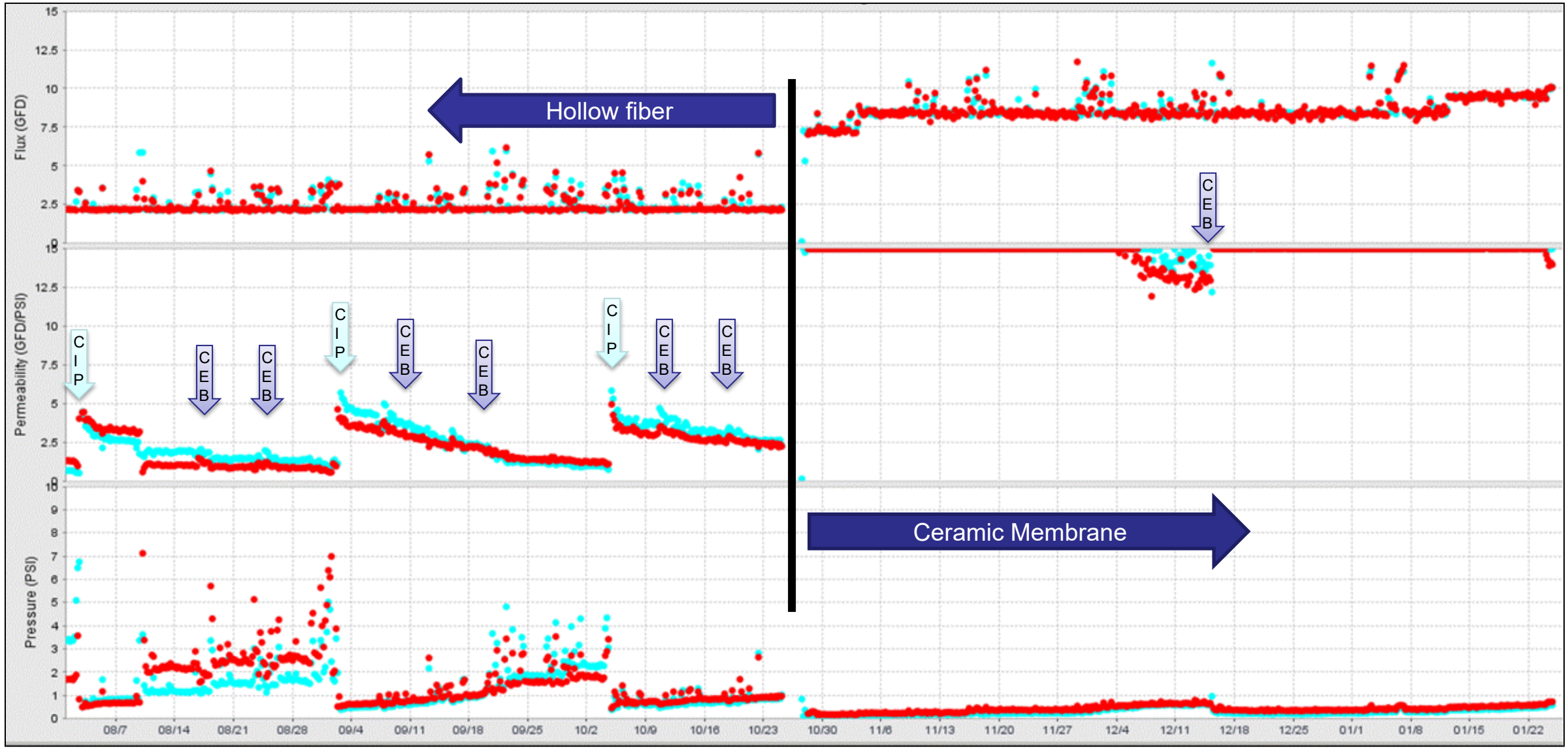
Basin configuration			Peak Design Flow				Average Design Flow			
Towers per Tank	Modules per Tower	Total Modules	GPD	GPM	GFD	CEB Interval (d)	GPD	GPM	GFD	CEB Interval (d)
4	8	64	74,880	52	18.1	1	43,200	30	10.5	14
4	9	72	74,880	52	16.1	5	43,200	30	9.3	21
4	10	80	74,880	52	14.5	7	43,200	30	8.4	30
4	11	88	74,880	52	13.2	10	43,200	30	7.6	30

Commercial System Installation

Removed fibers

Installed ceramics

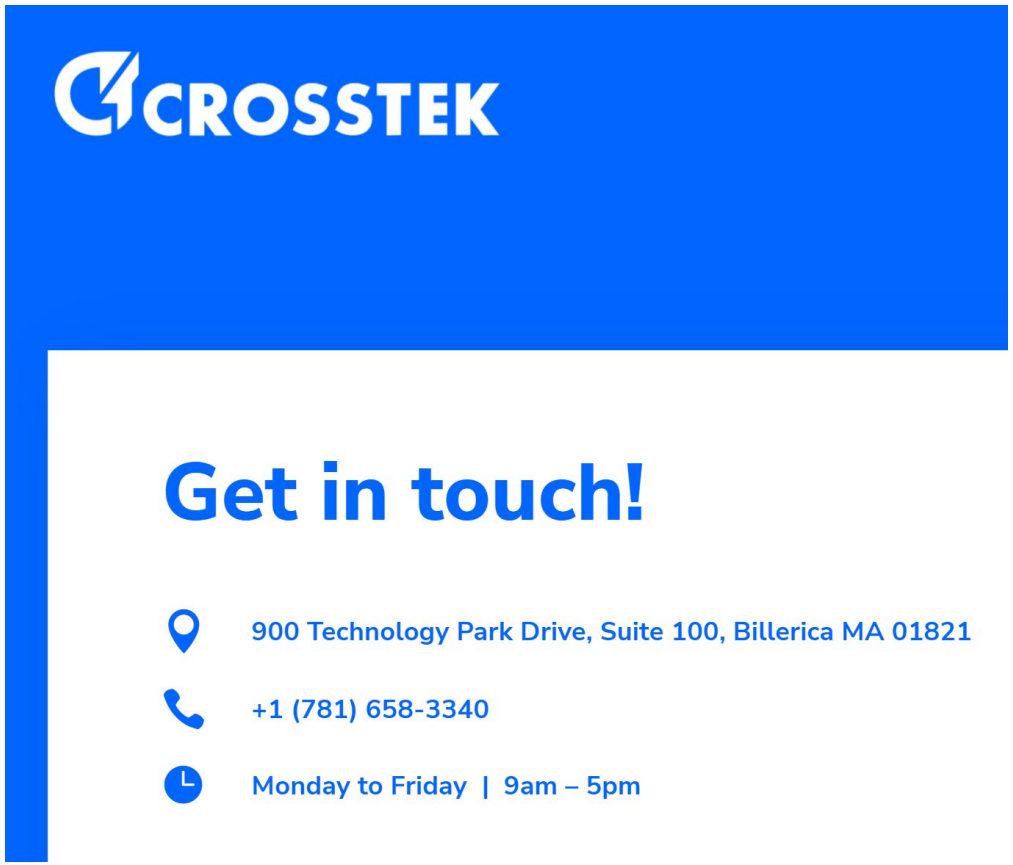
Commercial Operation: Successful



Closing comments

- Emulsified oils are challenging for hollow fiber MBRs leading to excessive fouling and labor-intensive cleaning
- Silicon carbide ceramic membranes were selected, and a successful pilot trial was performed meeting design goals
- Retrofit required 3 days downtime and repurposed all process equipment and PLC/HMI code
- Ceramic: 3x Flux, 3x Permeability, 9x less cleaning
- Question: is this better than a 2-step process: (1) enhanced de-oiling (2) hollow fiber MBR?

Thank you. Any questions?



stanton.smith@crosstek.com
617.460.9433