West Basin's Universal Membrane System – Pressurized PVDF Performance Pilot Program Particulars

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Introduction to West Basin

West Basin is a public agency that provides imported drinking water and recycled water to 17 cities and nearly one million people in the coastal Los Angeles area. West Basin is member agency of the Metropolitan Water District of Southern California. West Basin is an internationally recognized expert in water recycling, conservation, water education and water resource management, and currently treats over 40 million gallons a day (mgd) of secondary municipal effluent to produce five different recycled water qualities.

Introduction

Historically, the majority of major microfiltration (MF) and ultrafiltration (UF) membrane systems have been provided by suppliers that incorporate proprietary features into their modules and system designs. These proprietary features are not easily adaptable to alternative concepts when equipment repair or membrane replacement is required. As a result, membrane replacement is usually sole-sourced to the proprietary system supplier and subject to the commercial practices and potential limitations of the equipment and membranes provided by that supplier.

Recently, a number of membrane module suppliers have entered the market and offer an alternative method of delivery for MF/UF products. The module supplier works with an Original Equipment Manufacturer (OEM), who is responsible for designing the system to satisfy the requirements of the membrane module supplier. Although the relationship between the module supplier and OEM can be exclusive, some OEM's can offer multiple membrane products, and have recently begun to offer system designs which may be able to use more than one type of membrane module.

There can be variability within proprietary or non-proprietary membrane modules that may impact operation of a facility. Issues such as fiber breakage, potting failures, and variability of membrane product performance have led some suppliers to alter designs and introduce new products to replace existing products when performance is unacceptable.

When proprietary hardware such as manifold and module frame assemblies are considered, there have been instances of failure or product obsolescence resulting in unanticipated and expensive retrofit replacement necessary to maintain system operation.

West Basin found that retrofit/replacement of the 25 older proprietary microfiltration units used at various locations was more expensive than simply replacing the system itself[1].

As part of the on-going effort to improve operation at its facilities, West Basin began to review specifications for some the latest generation of pressurized MF/UF modules and found that there is a substantial level of consistency among PVDF current product offerings as shown in Table 1.

Table 1 summarizes the similarities and differences between alternative membrane modules.

Membrane		Dow	Econity	GE	Hydranautics	Pall	Puron	Scinor	Toray
General									
Material	Polymer	PVDF	PVDF	PVDF	PVDF	PVDF	PVDF	PVDF	PVDF
Model	Part Number	SFD-2880	PF-90M	ZW-1500	HYDRAcap MAX 80	UNA-620A	MP 8081-102	SMT600-P50	HFU-2020
Configuration	Direction	Outside In	Outside-In	Outside-In	Outside-In	Outside-In	Outside-In	Outside-In	Outside-In
MFG Process	Type	DIPS/NIPS	TIPS+Stretch	TIPS	TIPS	TIPS	n/a	TIPS	TIPS
Supported	unsupported	unsupported	unsupported	unsupported	unsupported	unsupported	Polyester	unsupported	unsupported
Pore Size	microns	0.03	0.1	0.02	0.08	0.1	0.03	0.1	0.02
Inside Diameter	mm	0.7	0.7	0.47	0.6	0.65	1.5	0.7	0.9
Outside Diameter	mm	1.3	1.2	0.9	1.2	1.1	2.6	1.3	1.5
Area	ft2	829	969	550	1130	538	546	538	775
Area	m2	77	90	51.1	105	50	50.75	50	72
Operating Flux	gfd	24-70	25-100	20-80	20-65	20-80	20-80	30-70	20-80
Operational									
Static Pressure	psi	90	38	40	73	45	45	60	44
Max. Forward TMP	psi	30	22	40	30	35	25	45	44
Backwash TMP	psi	38	38	40	30	35	10	35	44
Maximum Temperature	C	40	40	40	40	40	40	40	40
Operating pH Range	units	2-11	1-9	5-10	4-10	3-11		1-11	1-10
Backwash	type	air/water	air-water	air/water	air/water	air/water	air/water	air/water	air/water
Air Flow/module	SCFM	7 scfm			7.3-9.1 SCFM	3 SCFM	9 SCFM	3.1-7.5	3.5 SCFM
Water Direction	Feed/Filtrate	Filtrate	Filtrate	Filtrate	Feed	Filtrate	Feed/Filtrate	Filtrate	Filtrate
Cleaning									
Cleaning Temperature	C	40	40	40	40	40	40	40	40
Cleaning pH Range	units	2-11	2-11	2-11	1-13	3-12	1.8-10.5	1-13	0-12
Maximum Free Chlorine	mg/L	2000	1000	1000	5000	5000	1000	5000	2000
Periodic Cleaning	yes/no	yes	yes	yes	yes	yes	yes	yes	yes
Frequency	hours	12-72	12-72	12-72	12-72	12-72	12-72	12-72	12-72
Duration	min	20-60	20-60	20-60	20-30	20-60	20-60	20-60	20-60
Chlorine Concentration	mg/L	200	200	200	200	200	?	200	200
Physical									
Length	mm	2360	2000	1920	2340	2160	2060	2160	2160
Diameter	mm	225	260	180	250	180	220	180	216
Feed Connection	mm	50	80	50	50	50	32	50	50
Feed Connection	orientation	off axis	on-axis	on axis	on axis	on axis	off-axis	on axis	on axis
Feed Connection	Style	victaulic	victaulic	victaulic	victaulic	victaulic	victaylic	victaulic	victaulic
Filtrate Connection	mm	50	80	50	50	50	32	50	50
Filtrate Connection	orientation	off axis	off axis	on axis	on axis	on axis	off-axis	on axis	on axis
Filtrate Connection	Style	victaulic	victaulic	victaulic	victaulic	victaulic	victaulic	victaulic	victaulic
Backwash Connection	mm	50	65	32	50	32	32	32	50
Backwash Connection	orientation	on axis	on-axis	off axis	off axis	off axis	on-axis	off axis	off axis
Backwash Connection	Style	union	victaulic	union	victaulic	union	victaulic	union	victaulic
Air Scour Connection	Style	3/8"	n/a	n/a	3/8"	n/a	1/2"	n/a	n/a
Air Scours Size	in/mm	NPT	n/a	n/a	NPT	n/a	OD Tube	n/a	n/a

Figure 1 shows the scaled representation of current membrane modules which generally have the characteristics described as follows:

- PVDF membrane fibers encased into a replaceable pressure vessel module
- Similar backwash intervals and procedures using air and water
- Similar chemical cleaning intervals and procedures
- Nominal membrane module area of 40-105 square meters
- Similar connection sizes and orientations.

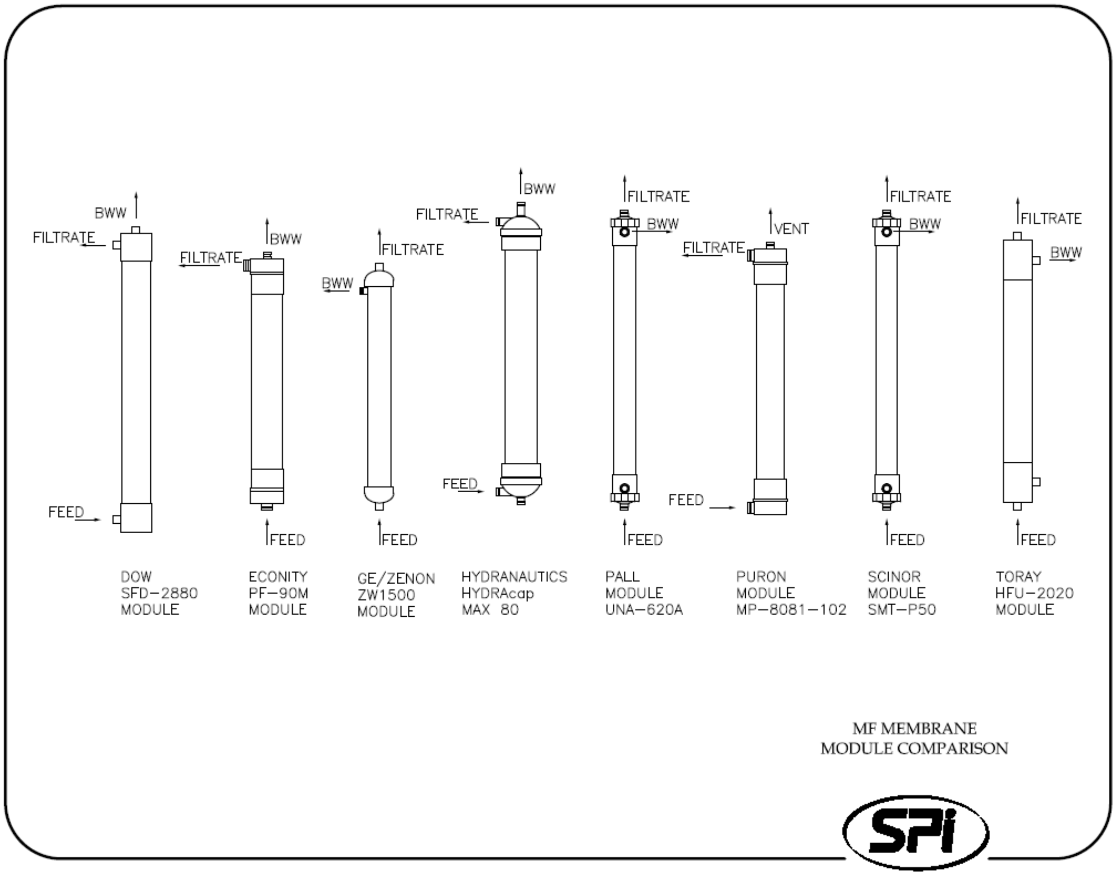

Figure 1: PVDF Membrane Module Comparison

West Basin's Universal Pilot Approach

Given its historical use of MF/UF membrane process for the treatment of recycled water, and the recent success with the installation of a PVDF membrane filtration system at the Edward C. Little Facility Water Recycling Facility (ECLWRF), West Basin developed an alternative approach for the evaluation of membrane modules for future or replacement needs. This approach involves the evaluation of membrane modules products on a West Basin designed and provided pilot unit, using a common or "Universal" approach in lieu of a supplier or OEM provided unit.

West Basin and Separation Processes, Inc first developed general criteria for membrane modules that were commercially available at the time. The module parameters are as follows:

- Vertically Oriented
- Up to 10 inches in diameter
- Up to 8 feet (nominally) in length.
- Bottom Feed / Drain and Air Scour
- Top Side or Top Center Filtrate
- Top Center or Top Side Upper Backwash Connection

Next criteria from the membrane unit were established. The membrane pilot unit will be configured to complete the following process sequences.

- 3 individually programmable membrane modules
- Each membrane section capable of the following process sequences
    - Filtration
    - Backwash
    - Chemically Enhanced Backwash (Chlorine or Citric Acid Addition)
    - Membrane Integrity Testing (feed or filtrate)
- Common feed, filtrate and CIP tanks.
- RO permeate for CIP and CEB processes.
- Common air supply.

West Basin proceeded with the development of plans and specifications for the construction of a pilot unit to satisfy its objectives and demonstrate the viability of its approach. Figure 2 shows the overall process arrangement of the proposed membrane unit.

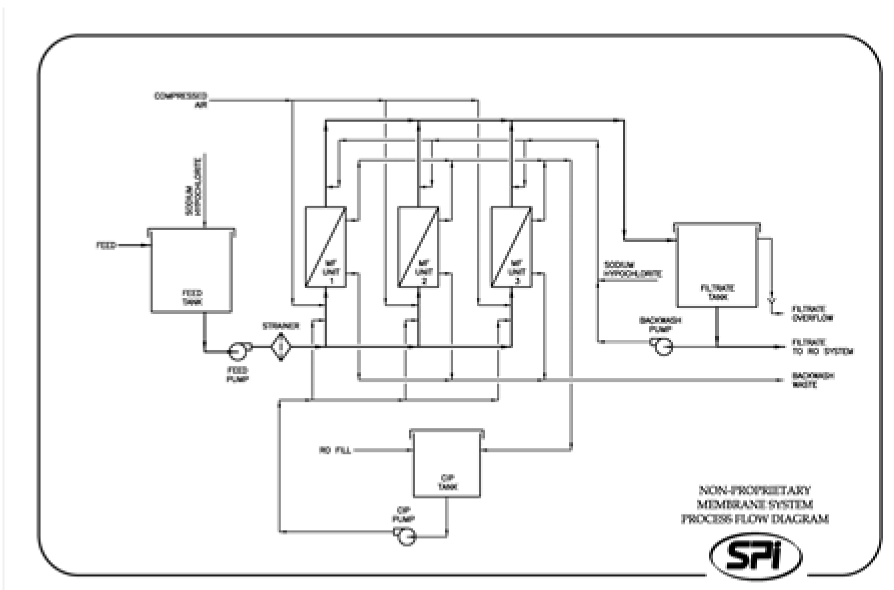

Figure 2: Universal Membrane System Schematic

A key element of the specification development was the decision that parameters for operation for each of the membrane modules could be individually programmed through the operational interface. This approach increases the flexibility to control the unit, and eliminates the need for a Programmer to make changes to the process sequence. In order to facilitate operation, the pilot system was provided with an internet connection for remote operation and transfer of historical data.

Pilot Unit Construction

Plans and specifications for construction of the pilot unit were competitively bid, and construction was awarded to H2O Innovations. Figure 3 shows the Pilot Unit installed at West Basins Edward C. Little Water Recycling Facility.

Figure 3: Universal Membrane System Pilot

The pilot unit was received in July. Installation was delayed by site specific issues and active commissioning was delayed unit September.

Initial Testing Program

Tertiary Filtered (a.k.a. Title 22) Recycled Water from ECLWRF is used as feed water to the universal pilot unit. This water was chosen as the supply for this evaluation as being representative of water that is available within the West Basin distribution system including sattelite facilities located in Carson and Torrance, CA.

West Basin is contemplating the replacement of existing proprietary MF equipment located at those facilities with a Universal MF system. Evaluation of PVDF membranes would provide information necessary to qualify suppliers that may be used as part of a replacement or future expansion effort.

The representative T-22 feedwater quality is shown in Table 2:

Table 2: Feed Water Quality (2014, monthly averages, mg/L unless stated otherwise)

Parameter		Raw Water	
		Avg.	Range
Inorganic Constituents (mg/L unless otherwise stated)	Sodium	199	172-235
	Calcium	63	46-73
	Magnesium	30	23-36
	Potassium	20	18-22
	Iron	0.28	0.25-1.55
	Manganese	0.16	0.11-0.21
	Bicarbonate(mg/L as CaCO3)	269	236-336
	Chloride	320	260-378
	Sulfate	160	121-191
	Nitrate-(mg/L as N)	2.0	0.9-3.85
	Ammonia (mg/L as N)	41	32-49
	Total Phosphate	1.09	8.83-1.75
	Orthophosphate	0.74	0.46-1.12
	Silica	16	13.5-18.1
General Parameters Physical Characteristics	Total Dissolved Solids (mg/L)	934	640-1100
	Total Hardness (mg/L as CaCO3)	297	222-419
	Alkalinity(mg/L as CaCO3)	269	236-306
	Turbidity, (NTU)*	1.3	0.8-2.3
	Temperature (^{o}C)	25	20-29
	pH, (pH units)	7.1	6.8-7.4
	Total Organic Carbon (mg/L)	10.0	8.5-13.2

PVDF Module Selection

While the pilot system was being constructed, a survey of pressurized MF products was made, identifying products of similar physical configuration, membrane properties and operating processes to determine modules for evaluation. The preliminary test plan indicated that a total of 6 membranes would be evaluated to assist in the selection of membrane modules for testing, A technical memorandum was prepared to identify membrane modules for evaluation and preferences with the following common characteristics:

- PVDF Membrane
- Homogenous Fiber Cross Section (TIPS or Similar)
- Bottom Feed
- MF or UF viewed as equally acceptable
- Low incidence of fiber breakage
- Compatible with chloraminated water
- High surface are per membrane.

Based upon discussions with various entities, the following membrane modules were ultimately selected.

- Group 1
  - Toray – HFU-2020
  - Dow – SFX-2880XP
  - Scinor – SMT600-P50
- Group 2
  - Econity – PF-90M
  - Hydranutics - HYDRACap Max 80
  - Pall – UNA-620A

Once the Group 1 membrane modules were installed, the individual manufacturers specified the operational sequences to be programmed into the unit. The sequences that required programming were as follows.

- Filtration (flow setpoint)
- Backwash (using MF filtrate)
- Chemically Enhanced Backwash (using RO permeate, and Sodium hypochlorite or Citric Acid)
- Integrity Testing (Feed or Filtrate)

Programming of the operational interface allows the operator to establish valve position, flow and duration, uniquely for each membrane module and for each sequence. The air flow required for backwashing is set manually using the installed rotometer. The test schedule is provided in Table 3.

Table 3 Schedule for Phase 1 (Group A shown, Repeat for Group B)

Test	Duration	Flux (gfd)	Backwash/CEB
0	1 day	CIP + Clean Water Test	n/a
1A-1	7 days*	25 gfd	Manufacturers
1A-2	7 days*	30 gfd	Manufacturers
1A-3	7 days*	35 gfd	Manufacturers
1A-4	7 days*	40 gfd	Manufacturers
1A-5	21 -30 days	Flux at TBD gfd	Manufacturers
1A-6	21 -30 days	Flux at TBD gfd	Manufacturers

* Subject to change, In the event that maximum TMP for the membrane is exceeded the run will be terminated and the membrane will be cleaned and restarted at a lower flux.

Based upon prior evaluations it is anticipated that the operating membrane flux for the membranes to be tested will be somewhere between 25 and 40 gfd, In order to determine the maximum stable membrane flux, membranes located on the pilot unit will be operated for a period of one week. At the end of the week, the performance will be reviewed, and if the performance of the membrane appears to be stable, (e.g. an increase in TMP of less than 25 percent of the maximum allowable TMP for the module considered over the period of 7 days) a decision will be made by to increase the flux to the next highest amount (target). If the membrane exceeds its maximum TMP during the period of testing, the membrane will be removed from service and cleaned prior to restarting.

The overall objective is to identify the membrane flux that results in stable operation over a 21 to 30 day projected cleaning interval that is historically used at West Basins facilities.

Operational Results

The pilot unit began operation on Recycled water on October 20, 2015 and operation will continue for the next few months until all membrane modules are evaluated. Results for operation are shown in Figures 4, 5, and 6 respectively.

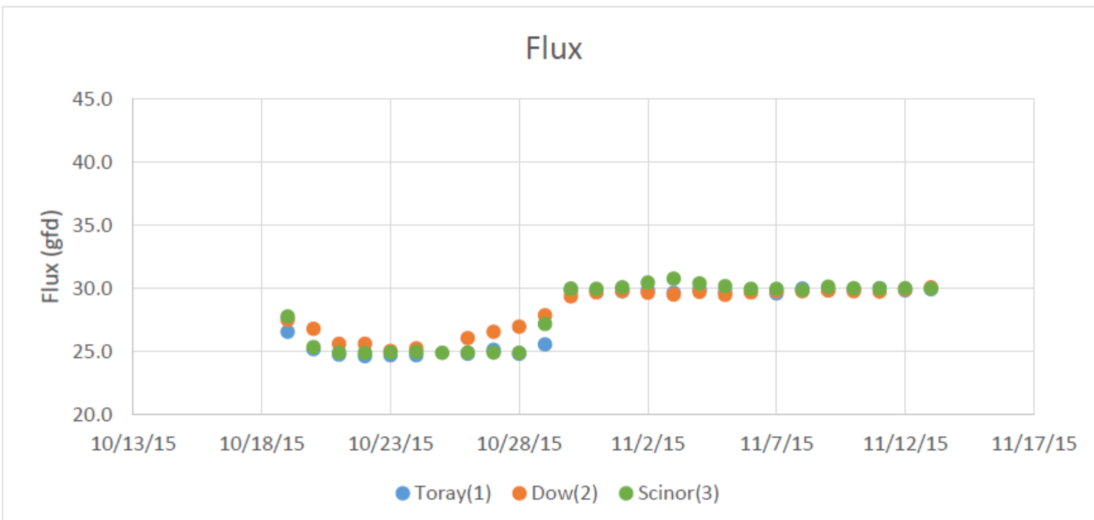

Figure 4: Membrane Flux

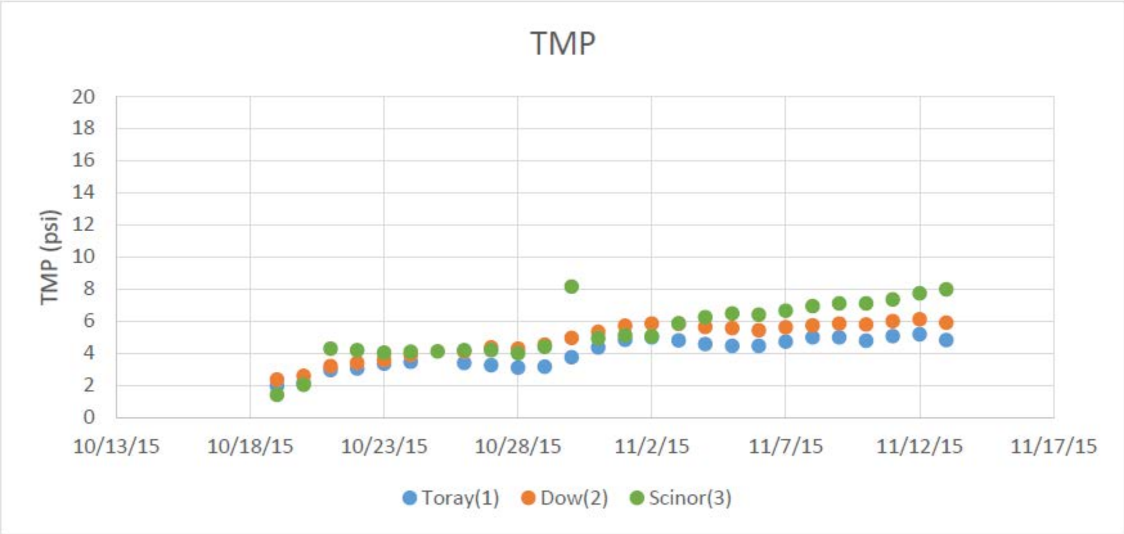

Figure 5: Membrane TMP

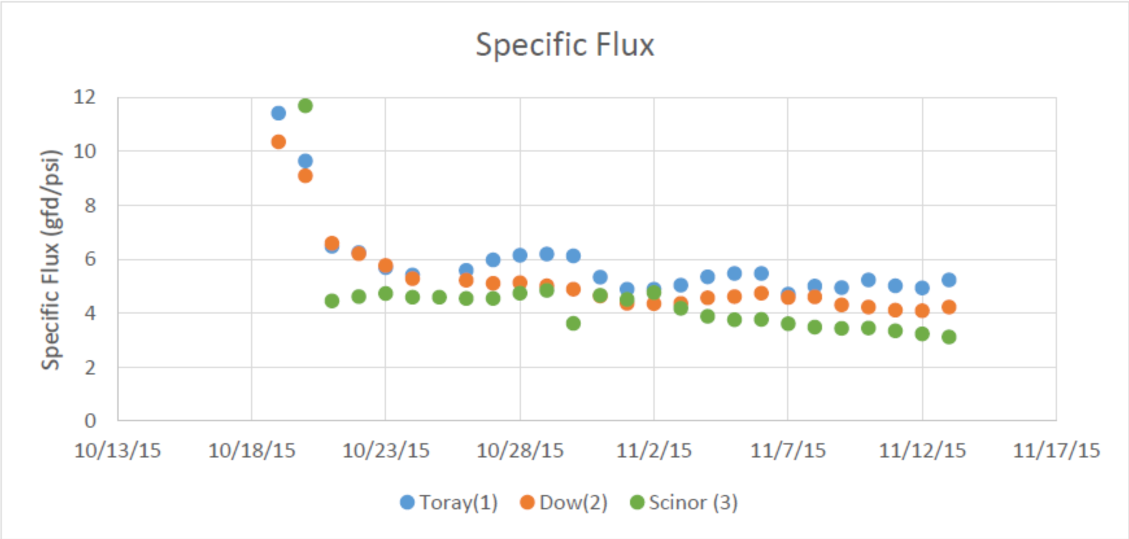

Figure 6: Membrane Specific Flux

Conclusions

West Basin believes that the use of a non-proprietary design offers the owner the following benefits.

- Greater control over the initial and future selection of membrane modules
- Elimination of expensive replacement proprietary component parts
- “Open Source” transparency in PLC and HMI programming
- Improved functionality of the operator interface.
- Flexibility in instrumentation and valve selection
- Customization of design to satisfy project specific space limitations

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- Dan Dragland – H2O Innovations
- Scott Sedey – H2O Innovations
- Gabriella Handley – Separation Processes Inc.

References

[1] “When Replacing Modules Just Isn’t Enough: West Basin’s Microfiltration System Replacement Evaluation,” Frank Fuchs, Kevin Tirado and Eric Owens. AWWA/AMTA Membrane Technology Conference, February 25-28, 2013, San Antonio, Texas.