BACK TO THE FUTURE: INNOVATION & ENERGY EFFICIENCY ON A LOW TDS BWRO RETROFIT/EXPANSION

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Abstract

The Ocean Reef Club is an exclusive, private golf club and community located in North Key Largo, Florida. The property encompasses two 18-hole golf courses and utilizes reverse osmosis to augment its daily irrigation requirements. The operation of the utilities is by the North Key Largo Utility Corporation.

In 2013, the NKLUC/Ocean Reef Club planned to either purchase new RO equipment or modify their existing skids to increase their irrigation water capacity. There was also a design desired, if possible, to incorporate the existing trains because all had new membrane as well as new pumps. The capacity increase had to address energy efficiency and became a focus of whichever method of delivery was presented.

During the evaluation phase, Sea Level Systems presented to the Board of Directors an innovative design. The modernization not only satisfied the required additional capacity, but also resulted in a compelling reduction of specific energy consumption. The Sea Level System design was ultimately chosen as the Club's most efficient solution and SLS was contracted in 2015 to manifest their innovation.

The concept of this expansion design was to utilize energy recovery technology to increase production capacity of each of the existing RO trains by 50% while maintaining use of the existing high-pressure feed pump and membrane arrays. The capacity was increased by installing a new rack of 6 pressure vessels alongside the existing modules. The new pressure vessels were ultimately tied into the existing feed and concentrate headers and they now operate at the same pressure as the older existing unit.

I. BACK…

The exclusive private golf club community of the Ocean Reef Club has a long history with specialized water treatment for irrigation purposes. Although the Florida Keys Aqueduct Authority supplies potable water for residences and commercial applications on the property, the golf course needed to maintain its water independence during times of drought and any other conditions that would limit the amount of watering required to keep the courses green.

Therefore, circa 1969 the Club commissioned a 4" seawater reverse osmosis system provided by Envirogenics utilizing the Envirogenics 4" CA SWRO membrane. This unit was one of the first RO systems placed in the state of Florida as well as in the USA. It ran successfully as a 2-Pass seawater system until circa 1973.

At that time, the irrigation RO system for Ocean Reef was transformed from the 4" sizing to 8" Envirogenics CA membranes and the feedwater source was converted to brackish well water supply.

In 1974-1975 members of the exclusive ORC were somewhat dismayed when the Club itself promoted its two golf courses to not only the members, but also member-guests. As well, the property maintained a Convention Center and when events took place, the exhibitors and attendees could play the two courses.

This ease of use created a somewhat non-stop golfing situation for the two courses.

Full members were determined to combat their inability to play due to the number of golfers on the courses. They ultimately decided to build their own 18-hole course now known as the Card Sound Golf Club. Card Sound is a members-only course. Problem solved…

Except…this new course also required augmentation of its irrigation needs to maintain water independence. Therefore, another reverse osmosis system was commissioned by Polymetrics and they installed a seawater unit utilizing 4" DuPont B-10's. This positioned the Ocean Reef unit on the north side of the building and the Card Sound unit on the south side. Then, and now, the North Key Largo Utilities Corporation (NKLUC) oversaw and continues to oversee operations of all water treatment units at the Ocean Reef Club.

Circa 1979/1980, NWISA (later changed to ADA and then changed to AMTA) had their annual membrane water treatment conference and the facility was utilized as the Conference plant tour.

In 1985, two additional skids of 425,000 GPD each were installed by Basic Technologies, Inc. With the three-skid configuration, there was 1.275 MGD available for Ocean Reef golf irrigation.

It was not until circa 1987, that the Polymetrics Card Sound unit was replaced and converted to a well water supply utilizing 8" thin film spiral wound membranes. That unit is still in operation today with interim membrane replacement and slight modifications.

Circa 1992, the Ocean Reef Club once again modified its brackish RO units for additional capacity. And, in 2004, an additional set of modifications was completed on the Card Sound unit wherein energy recovery was introduced to the unit utilizing ERI pressure exchanger components. (*John P. McHarg/Stuart A. McClellan, Journal AWWA, 11/2004*)

In 2009 two additional specialized RO units were placed in the Card Sound side of the building by Hydropro, Inc. to augment capacity for irrigation purposes. These two units (150,000 GPD each) were utilized in conjunction with the MBR advanced wastewater facility installed to increase efficiencies in wastewater treatment. These RO units were designed and are currently used to treat effluent from the MBR for distribution in the irrigation holding ponds. They are only used in the off seasons of resident capacity due to higher salinities from the MBR during periods of high resident capacity. (*B.D. Goodin, SEDA Fall Symposium, 10/2011*)

In 2013, the NKLUC/Ocean Reef Club desired to either purchase new RO Equipment or modify their existing skids to once again increase their irrigation water capacity. The capacity increase had to address energy efficiency and became a focus of whichever method of delivery was presented.

During the evaluation phase, Sea Level Systems presented to the Board of Directors an innovative design. The modernization not only satisfied the required additional capacity, but also resulted in a compelling reduction of specific energy consumption (or increase in efficiency). The Sea Level System design was ultimately chosen as the Club's most cost and energy efficient solution and SLS was contracted in 2015 to manifest their innovation.

II. TO…

The proposed design uses energy recovery technology to increase the production capacity of each of the existing reverse osmosis trains by 50% while continuing to use the existing high-pressure feed pump and membrane arrays. To increase capacity, a new rack of six pressure vessels was installed alongside the existing modules. The new pressure vessels were ultimately tied into the existing feed and concentrate headers and operate at the same pressure as the older unit.

It was a contract requirement that when one skid was being modified, the other two skids had to remain in continual operation. This requirement was accomplished without issue throughout the installation process.

Two isobaric PX® Pressure Exchangers® from Energy Recovery, Inc., model PX-180B, were installed to transfer the hydraulic energy from the concentrate to a new side stream of filtered feed water.

The concentrate exits all the pressure vessels at high pressure and is collected in a new concentrate header. The concentrate in this high-pressure header passes through the high-pressure flow sensor and enters the Pressure Exchangers (PXs), which transfer most (more than 97%) of the hydraulic energy in the concentrate stream to a side stream of feedwater. After exiting the PX array, the wastewater passes through the low-pressure concentrate flow sensor and a passive flow controller that prevents the concentrate flow from exceeding the maximum capacity of both PX units (360 gpm).

After now being pressurized by the PXs, this new side stream of feed water is boosted in pressure by an additional 30 psi by a booster pump so it can be blended into the main high-pressure pump discharge, increasing the feed flow to all vessels.

A variable frequency drive (VFD) was installed to control the speed of the new booster pump, which allows for adjustment and balancing of flow through the PX devices. A VFD was also installed to control the existing high-pressure pump speed. This was another energy saving modification for this project, as the high-pressure feed pump was previously throttled back to control feed pressure. The two VFDs and a low-pressure concentrate flow control valve are used to adjust the flow and pressure of the expanded system to the desired operating conditions. In addition, a new micron filter housing (identical to the existing two) was supplied and installed to handle additional feed water requirements of the expanded trains.

The design of the new Brackish Water Reverse Osmosis equipment minimizes corrosion and maintenance problems on downstream process equipment associated with saline waters and harsh environments. All low-pressure piping and structural materials were fabricated from plastics or Fiberglass Reinforced Plastic (FRP), all high-pressure piping was constructed of 316 stainless steel, and all other metallic materials in contact with the water are of 316SS construction or better.

III. THE FUTURE…

After installation of all components for modification of each train, each train underwent pre-startup checkout to confirm proper installation and functional testing. The instruments were powered up, the analog output range was calibrated and units of flow changed to gpm. The PX Booster pump was bumped and proper rotation was verified.

After functional checkout, the inlet valve was opened and the train was slowly filled with water. As the air was purged from the system, the newly installed piping was checked for leaks.

After all the air was purged and any leaks were repaired, each newly expanded RO train was then manually started via the new control system according to the following sequence of operation. This initial manual startup included extended flush times to ensure all air was purged before reaching operating pressure.

Startup Sequence

1. The RO system startup is initiated as normal by allowing feed water to flow into the RO unit by starting a feed water supply pump and manually opening the RO unit feed isolation valves at the inlet of the high-pressure pump and the PX devices.
2. The feed water entering the RO unit will flow through the PX devices and may or may not cause the rotor to rotate. With the feed water supplied to the RO unit at a constant pressure, the flow through the PX will be regulated by the flow controller and should be verified by the operator on the low pressure concentrate flow meter. The RO system piping has been designed to prevent drainage while shut down, consequently normal startups should only require short preflushes of about 30-60 seconds. However, if air has entered the system (due to maintenance or repairs) the operator should vent all high and low-pressure lines and flush the system until all the air is purged.
3. After all the air is purged and the system is full of water, the PX Booster pump is started. This will begin circulation in the high-pressure side of the PX devices and throughout the high-pressure piping of the RO unit. The PX rotors should be rotating at this point and can be verified by a humming sound audible at proximity to the PX devices. The speed of the PX Booster pump should be preset in the VFD, such that the flow through the high-pressure side and the low-pressure side of the PX piping is equal. Continue flushing with the circulation pump on as necessary until all air is removed from the system.

4. After the feed water supply and circulation pump have run for sufficient time to purge all air from the system, the high-pressure RO feed pump and the scale inhibitor dosing pump can be started. The RO system pressure will increase to the point where the permeate flow is approximately equal to the flow from the high-pressure RO feed pump, and the unit will be in steady-state production. As system pressure increases, the sound level from the PX will also increase.

Shutdown Sequence

1. The RO system shutdown sequence is essentially the reverse of the startup sequence.
2. When a shutdown is initiated, the run signal for the scale inhibitor dosing pump is stopped, and the high-pressure RO pump ramps down to stop.
3. The post flush continues with the PX Booster pump operating and the PX rotor still spinning, circulating feed water throughout the RO system high pressure piping. When the system pressure decreases to the osmotic pressure of the feed water (approximately 75 psi) and the salinity of the brine is within 10% of the feed, the PX Booster pump is stopped.
4. The feed supply pump is shut down and / or the feed isolation valves on the PX inlet and RO pump inlet are closed.
5. Some pressure will remain and slowly decrease as permeate suck-back equalizes the osmotic pressure on both sides of the membrane, and the excess feed water slowly bleeds out through the PX bearing gap.

After the unit was started up and running satisfactorily in manual, the unit was shut down and the automatic start and stop sequences were tested. The pre-flush times were adjusted to allow for brief purging of air on startup for both the well flush and the PX Booster flush. For sufficient purging of concentrated salts upon shutdown, the post flush timer was adjusted such that the conductivity of the brine streams was reduced to within 10% of the feed water conductivity.

In addition to the data logged by the SCADA system, a membrane system supplier representative was onsite during the test to monitor system status, record data, make adjustments, and verify instrument readings. Data points for the initial startup of each train are included in this report.

III.1 - EXPANDED RO TRAIN 1 STARTUP

SUMMARY

The startup for RO Train 1 began on April 7, 2016.

Upon initial startup, incremental adjustments were made to the high and low pressure concentrate flows to balance them at the 294 gpm setpoint. The PX LP OUT flow control valve was adjusted along with the PX Booster pump VFD speed setting to achieve a flow balance to within 5%. The permeate flow was set by adjusting the high-pressure RO pump VFD speed.

RESULTS & DISCUSSION

Ro Train 1 performed well throughout all phases of operation. After running at a lower permeate flow rate of 380 gpm for a short duration, the unit was brought up to the desired flow of approximately 410 gpm (590,00 gpd). Maximum design permeate flow is 443 gpm (637,500) however the units are usually run at 5-10% below maximum capacity.

The PX LP Inlet had good feed pressure (47 psi) throughout the startup and the PX LP OUT flow control valve had to be closed several turns (~65% open) to lower the PX LP OUT flow to within 5% of the PX HP IN flow of ~294 gpm.

Operating Data:

After the RO unit operating parameters were adjusted and the unit was running at steady state for about an hour the following data points were taken:

NKLUC REVERSE OSMOSIS WTP EXPANSION TRAIN 1 STARTUP DATA 4/7/2016			
RO Train Pressure	**PSI**	**Flow**	**GPM**
Membrane Feed	244	Feed	713
PX HP IN	230	HP Concentrate	294
PX HP OUT	222	LP Concentrate	302
PX LP IN	47	Total Permeate	411
PX LP OUT	40		
LP Concentrate	34	PX Flow Balance	3%
Total Permeate	1.2	% Recovery (Membrane)	58.30%
		% Recovery (Overall)	57.6%
Differential Pressures	**PSI**		
Transmembrane	242.8	**Control Valve Position**	**% Open**
RO Array DP	14	PX LP OUT	65%
PX Array HP DP	8		
PX Booster DP	22		
		Feed pH	7.33
Conductivity	**µmhos**	**Feed temp `C**	27
Feedwater	11,210	**Permeate pH**	6.18
Membrane Feed	11,360		
HP Concentrate	24,260	**Vessel Conductivity**	**µmhos**
LP Concentrate	23,860	1	434.0
PX HP OUT	11,600	2	443.0
Total Permeate	335	3	451.0
		4	449.0
% Rejection System	97.0%	5	450.0
% PX Salinity Increase	1.3%	6	439.0

III.2 - EXPANDED RO TRAIN 2 STARTUP

SUMMARY

The startup for RO Train 2 began on April 21, 2016.

Upon initial startup, incremental adjustments were made to the high and low pressure concentrate flows to balance them at the 294 gpm setpoint. The PX LP OUT flow control valve was adjusted along with the PX Booster pump VFD speed setting to achieve a flow balance to within 5%. The permeate flow was set by adjusting the high-pressure RO pump VFD speed.

RESULTS & DISCUSSION

Ro Train 2 performed well throughout all phases of operation. The PX LP IN feed pressure was a bit lower than "normal" at 39 psi, possibly due to the configuration of well pumps and RO trains running and the longer length of 4" HDPE to the PX LP Inlet. Consequently, the flow with the PX LP OUT flow control valve fully open was only 290 gpm, but within the 5% range of PX HP IN flow.

The RO pump VFD speed was adjusted to set the permeate flow at 380 gpm (547,200 gpd), and the unit remained operating at this lower capacity set point.

Operating Data:

After the RO unit operating parameters were adjusted and the unit was running at steady state for about an hour the following data points were taken:

NKLUC REVERSE OSMOSIS WTP EXPANSION TRAIN 2 STARTUP DATA 4/21/2016			
RO Train Pressure	**PSI**	**Flow**	**GPM**
Membrane Feed	230	Feed	670
PX HP IN	217	HP Concentrate	300
PX HP OUT	207	LP Concentrate	290
PX LP IN	40	Total Permeate	380
PX LP OUT	33		
LP Concentrate	30	PX Flow Balance	3%
Total Permeate	2.0	% Recovery (Membrane)	55.88%
		% Recovery (Overall)	56.7%
Differential Pressures	**PSI**		
Transmembrane	228	**Control Valve Position**	**% Open**
RO Array DP	13	PX LP OUT	100%
PX Array HP DP	10		
PX Booster DP	23		
		Feed pH	7.33
Conductivity	**µmhos**	**Feed temp `C**	27
Feedwater	11,150	**Permeate pH**	6.16
Membrane Feed	11,620		
HP Concentrate	23,400	**Vessel Conductivity**	**µmhos**
LP Concentrate	23,300	1	659.0
PX HP OUT	12,200	2	676.0
Total Permeate	450	3	659.0
		4	705.0
% Rejection System	96.0%	5	710.0
% PX Salinity Increase	4.2%	6	697.0

III.3 - EXPANDED RO TRAIN 3 STARTUP

SUMMARY

The startup for RO Train 3 began on June 7, 2016.

Upon initial startup, incremental adjustments were made to the high and low pressure concentrate flows to balance them at the 294 gpm setpoint. The PX LP OUT flow control valve was adjusted along with the PX Booster pump VFD speed setting to achieve a flow balance to within 5%. The permeate flow was set by adjusting the high-pressure RO pump VFD speed.

RESULTS & DISCUSSION

Ro Train 3 performed well throughout all phases of operation. After running at a lower permeate flow rate of 380 gpm for a short duration, the unit was brought up to the desired flow of approximately 413 gpm (595,000 gpd).

The PX LP Inlet had good feed pressure (41 psi) throughout the startup and the PX LP OUT flow control valve had to be closed several turns (~70% open) to lower the PX LP OUT flow to within 5% of the PX HP IN flow of ~294 gpm.

Operating Data:

After the RO unit operating parameters were adjusted and the unit was running at steady state for about an hour the following data points were taken:

NKLUC REVERSE OSMOSIS WTP EXPANSION
TRAIN 3 STARTUP DATA
6/7/2016

RO Train Pressure	**PSI**	**Flow**	**GPM**
Membrane Feed	248	Feed	707
PX HP IN	237	HP Concentrate	289
PX HP OUT	229	LP Concentrate	294
PX LP IN	42	Total Permeate	413
PX LP OUT	35		
LP Concentrate	28	PX Flow Balance	2%
Total Permeate	0.0	% Recovery (Membrane)	58.83%
		% Recovery (Overall)	58.4%
Differential Pressures	**PSI**		
Transmembrane	248	**Control Valve Position**	**% Open**
RO Array DP	11	PX LP OUT	70%
PX Array HP DP	8		
PX Booster DP	19		
		Feed pH	7.35
Conductivity	**µmhos**	**Feed temp `C**	27
Feedwater	12,020	**Permeate pH**	6.12
Membrane Feed	12,300		
HP Concentrate	26,600	**Vessel Conductivity**	**µmhos**
LP Concentrate	25,930	1	779.0
PX HP OUT	12,480	2	748.0
Total Permeate	500	3	766.0
		4	793.0
% Rejection System	95.8%	5	791.0
% PX Salinity Increase	2.3%	6	787.0

IV. BACK TO THE FUTURE…

The overall system's design parameters of the Ocean Reef units now consist of a total permeate production of 410-442 gpm; recovery of 60%; membrane feed pressure of 250-290 psi; and a low pressure/high pressure concentrate flow through the PX devices of 273-294 gpm.

With this efficient design, NKLUC now receives 50% more volume per modified train for the same energy consumption previously required to run the original reverse osmosis units.

The overall history of Ocean Reef, Card Sound, and the MBR Reverse Osmosis reuse units makes this location an important historical site for membrane technology. The various units and their subsequent modifications through the years use(d) Seawater RO, Brackish RO, Brackish RO Energy Recovery and MBR reuse treatment.

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