MacHarg

Pressure Exchanger Helps Reduce Energy Costs

in Brackish Water RO System

By John P. MacHarg and Stuart A. McClellan

A device from Energy Recovery Inc. (ERI), which has been proven effective in hundreds of seawater reverse osmosis (RO) applications, has now been shown to save money in brackish RO plants as well. In the seawater desalination industry, ERI's Pressure Exchanger™ (PX™) is well known as a reliable energy-recovery device that dramatically lowers operating costs. Until recently it was unknown whether the PX could achieve similar results in brackish water applications, but in February 2004 this question was answered at the Card Sound Golf Club desalination facility at the Ocean Reef Club in Key Largo, Fla.

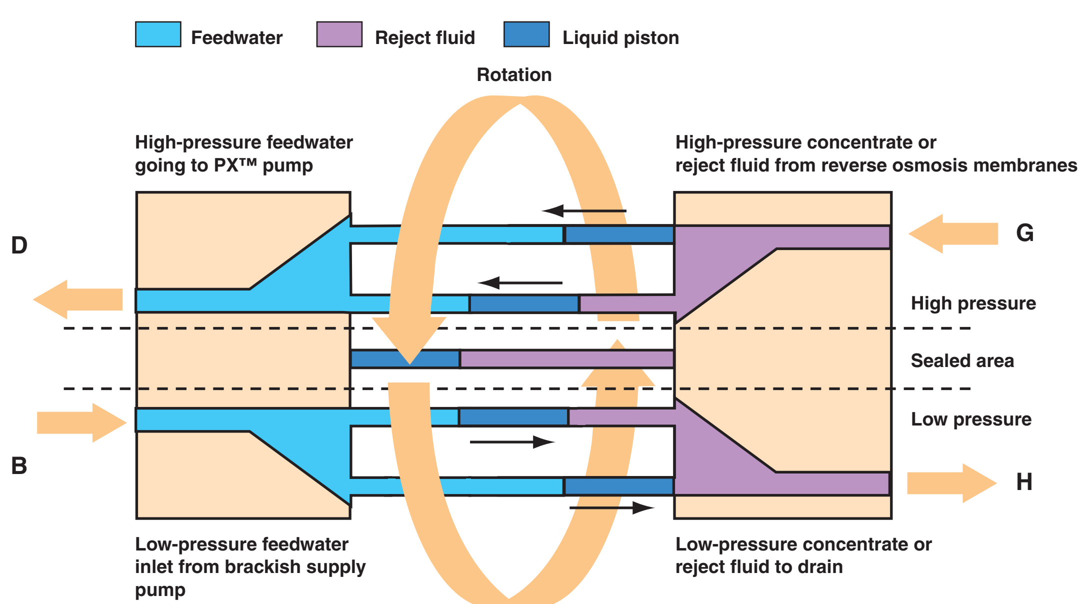
An ERI retrofit project at the Florida facility has shown that the PX can significantly lower the costs of brackish water RO applications—it is saving the Ocean Reef desalination facility an estimated $15,000 per year.

HOW THE PX WORKS

The PX unit uses the principle of positive displacement to pressurize filtered feedwater by direct contact with the high-pressure concentrate (waste) stream or the reject fluid from an RO system. Pressure transfer occurs in the longitudinal ducts of a ceramic rotor that spins inside a ceramic sleeve. The rotor-sleeve assembly is held between two ceramic end covers. At any given instant, half of the ducts are exposed to the side with high-pressure fluid and half are exposed to the side with low-pressure fluid. As the rotor turns, ducts pass a sealing area that separates the high-pressure side from the low-pressure side. This process is illustrated in Figure 1.

Feedwater pumped from the brackish water supply at low pressure flows into a duct on the left side of the figure. This flow expels concentrate from the duct on the right side of the figure. After the rotor turns past a sealed area, high-pressure

FIGURE 1 PX™ sectional view



PX—Pressure Exchanger™

concentrate flows into the right side of the duct, pressurizing the feedwater. Pressurized feedwater then flows into the high-pressure feed line going to the PX pump. This pressure-exchange process is repeated for every duct with each revolution of the rotor such that the ducts are alternately filling and discharging. At a speed of 1,200 rpm, one revolution is completed every 1/20 of a second.

Figure 2 and Table 1 show the flow path of a typical RO–PX system. The concentrate from the RO membranes (G) passes through the PX, where its pressure is transferred directly to a portion of the incoming feedwater at up to 91% efficiency. This pressurized stream of feedwater (D), which is approximately equal in volume and pressure to the reject stream, passes through a PX auxiliary pump (not the main high-pressure pump) to add back the small amount of pressure lost from the differential pressure across the membranes and from friction in the piping and the PX. The PX booster pump drives the flow through the high-pressure side (G and D) of the PX. Fully pressurized feedwater then merges with the main feedwater line of the RO system after the main high-pressure pump.

In an RO–PX system, the main pump is sized to equal the RO permeate flow plus a small amount of rotor lubrication flow, not the full RO feed flow. Therefore, the PX significantly reduces flow through the main pump. This point is significant because a reduction in the size of the main pump results in lower power consumption and operating costs.

TABLE 1 Flow rates and pressures at the Ocean Reef Club desalination facility

Diagram Location	Description	Flow Rate *gpm (L/s)*	Pressure *psi (kPa)*
A	Feed supply	495 (31.2)	28 (190)
B	PX™ low-pressure inlet	171 (10.8)	28 (190)
C	Main pump outlet	324 (20.4)	200 (1,380)
D	PX high-pressure outlet	171 (10.8)	184 (1,270)
E	PX pump outlet	171 (10.8)	200 (1,380)
F	Reverse osmosis feed stream	495 (31.2)	200 (1,380)
G	PX high-pressure inlet/reject	175 (11.0)	190 (1,310)
H	PX low-pressure outlet/reject	175 (11.0)	17 (120)
I	Product water	320 (20.2)	3 (20)

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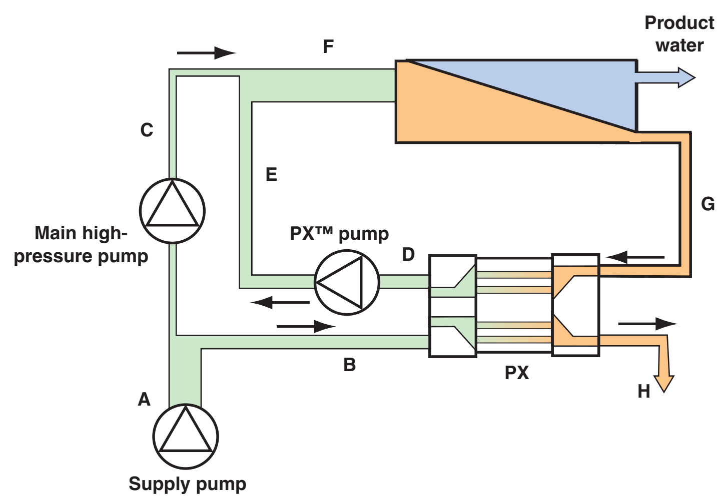
FIGURE 2 Typical PX™ system



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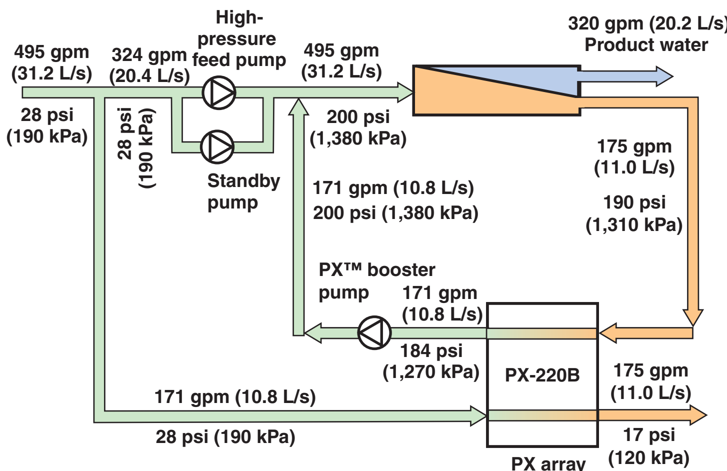
PX RETROFIT AT THE OCEAN REEF CLUB

ERI first learned of the Ocean Reef PX retrofit project in mid-2001. It was reported that the golf resort paid as much as $6/1,000 gal ($1.59/1,000 L) from the local water authority, which made onsite desalination an attractive cost-saving option. Because of its high efficiency, the ERI PX promised a capacity expansion with the lowest possible capital and operations and maintenance costs when compared with other energy-recovery technologies. However, many issues had to be overcome, including the installation of new raw water wells. There was also a question of whether the PX could produce adequate savings in this low-pressure brackish RO system.

Although the PX had proven itself in hundreds of seawater and several brackish water applications around the world, it had not yet been used in a brackish water plant in the United States. There was concern that the PX might not be a viable solution for the brackish treatment market because of the relatively low operating pressures. However, when the PX–220B was put online, the resulting power savings of 37% put these concerns to rest. The 0.46-mgd (1.74-ML/d) plant at the Ocean Reef Club saves 25 kW at $0.09/kW·h—which results in a projected savings of nearly $15,000 per year. Running with the PX, electricity costs are now around $0.20/1,000 gal ($0.05/1,000 L) at the facility.

FIGURE 3 The Ocean Reef Club's reverse osmosis plant



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The entire project included expanding the original plant by replacing and adding new membranes (12 pressure vessels with six elements[1]), replacing the old pumps with two new high-pressure pumps[2], and installing a booster pump[3] for the PX–220B energy recovery unit. The design included redundancy with two main pumps as shown in Figure 3. The high-pressure pumps can supply the total feed flow to the RO membranes, or one pump can be taken off-line and replaced with the PX system.

THE PX SIGNIFICANTLY REDUCES FLOW THROUGH THE MAIN PUMP. THIS POINT IS SIGNIFICANT BECAUSE A REDUCTION IN THE SIZE OF THE MAIN PUMP RESULTS IN LOWER POWER CONSUMPTION AND OPERATING COSTS.

The design offered an excellent platform to compare a standard brackish RO system with no energy recovery to a system with a PX (Table 2). The Ocean Reef retrofit demonstrates that the PX can provide significant savings in brackish water RO applications.

INTERSTAGE BOOSTER DESIGN

In some applications, even more savings are possible by applying the PX booster pump as an interstage booster pump in multistaged arrays. The PX system requires a booster pump to make up the small amount of pressure loss that occurs through the membranes, the friction in the PX, and the piping circuit. In single-stage systems, this pump is applied at the outlet of the PX (Figures 2 and 3). However, in a two-stage brackish water system, the PX booster pump can serve two purposes by being installed between stages 1 and 2 (Figure 4). In this configuration, the PX booster pump also acts as an interstage booster pump that helps reduce the required pressure from the main high-pressure feed pump and balance the flux between stages 1 and 2.

Figure 4 (page 48) shows that while the PX booster is supplying the energy to drive the water around the PX circuit, it is also providing 55 psi (380 kPa) of

TABLE 2 Power comparison at the Ocean Reef Club reverse osmosis plant

Project Stage	Feed Pressure *psi (kPa)*	Total Power *kW*	Product Water Flow Rate *gpm (L/s)*	Power Consumption/ Volume *kW·h/1,000 gal (3,785 L)*
Original system	300 (2,070)	60.8	200 (12.6)	5.06
Two new high-pressure pumps	200 (1,380)	63.3	340 (21.5)	3.10
One high-pressure pump and Pressure Exchanger™	200 (1,380)	37.8	320 (20.2)	1.96

TABLE 3 PX™ savings comparison in an interstage booster system for brackish water

Parameter	Standard Reverse Osmosis	Energy Recovery Inc.
Feed pump efficiency—%	83	83
Feed pump motor efficiency—%	94	94
Feed pump power—*kW*	172.9	130.3
Booster pump efficiency—%	80	80
Booster pump motor efficiency—%	94	94
Booster pump power—*kW*	23.2	31.8
Power consumption/volume—*kW·h/1,000 gal (3,785 L)*	2.19	1.82

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interstage boost pressure. In addition to improving the flux balance, the PX also results in significant savings by reducing the size of the main high-pressure pump and lowering the first-stage feed pressure inherent to an interstage booster design. Table 3 shows the power savings in a PX system versus a standard interstage booster system.

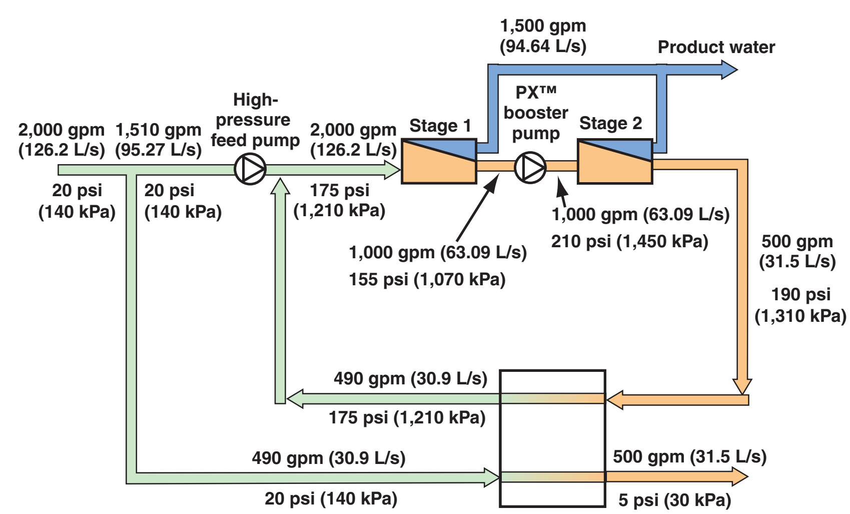
As Table 3 indicates, the PX results in savings of 17% when applied to a typical 75% recovery brackish water RO system. In this example of a 2.1 mgd (7.9 ML/d) system (and with a power cost of \$0.06/kW·h), the PX will save approximately \$17,500 per year.

The PX has been proven in hundreds of seawater applications around the world, and it has now been shown effective in providing similar power savings in lower-pressure, higher-recovery brackish water plants. With savings typically ranging between 10 and 30% in lower-pressure, higher-recovery systems, the PX may become as common in the brackish RO market as it is in seawater markets.

PHOTO: ERI

Energy Recovery Inc.'s retrofit installation at the Ocean Reef Club in Key Largo, Fla., shows (from left to right) the PX220-B, the reverse osmosis rack, the booster pump, and the high-pressure pumps.

FIGURE 4 Interstage booster PX™ design for a two-stage system



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FOOTNOTES

1. BW30-440, FILMTEC Products, The Dow Chemical Co., Midland, Mich.
2. 4×6–9 MPV, Afton Pumps Inc., Houston, Texas
3. 2×3–7 ILVS, Afton Pumps Inc., Houston, Texas