Highly Efficient Energy Recovery Devices

Energy Recovery Inc

September 2011

A White Paper on High Efficiency Energy Recovery Devices in Desalination Plants

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Executive Summary

➔ Overview

Energy Recovery Devices (ERDs) are at the core of saving energy in the operation of any seawater reverse osmosis (SWRO) desalination facility. Isobaric or “positive displacement” devices such as the ERI PX Pressure Exchanger™ (PX™) devices are the most efficient solution available today and can reduce the energy consumption of seawater reverse osmosis (SWRO) systems by up to 60 percent.

ERI has the largest installed base of ERDs in the industry. Considering only large desalination plants, ERI has a global installed base of over 9,700 individual PX devices in more than 400 desalination plants. Factory acceptance testing is done on 100% of the PX devices.

This paper will examine and quantify the efficiency of ERI PX devices based on an extensive database of actual test results. Significant historical performance data was evaluated and analysed to validate efficiency figures and guarantee increased efficiencies for several PX device models, including the PX Pressure Exchanger models PX-220, PX-260 and PX-300 units, The existing models offer 96.8% efficiency guarantees, which in turn offers significant energy savings for plant owners and operators.

Test data will also quantify the efficiency gains provided by ERI’s Quadribaric™ technology. ERI’s newest device, the PX-Q300 incorporates the innovative Quadribaric technology doubling the number of pressure exchanges per revolution.

This new PX-Q300 improves efficiency - with a warranted minimum efficiency of 97.2%.

Many of the globally installed units have been in operation for as long as 12 years. With zero failure as a result of PX technology designed ceramics, research indicates that PX devices will continue operating well into the future.

The Decision Drivers

In the seawater desalination industry, energy efficiency is a key component when evaluating the economics of a plant. In the seawater reverse osmosis (SWRO) process, power consumption is the largest component of the entire process – accounting for an estimated 30-40% of the total RO portion. Energy recovery devices were developed primarily for this reason- to reduce energy consumption by as much as 60 percent. By significantly minimizing energy costs, plant owners can positively impact the economics of their operations. When designing an ERD system for SWRO processes, key considerations should include:

- ➔ Energy recovery of highest efficiency, for its operational range.
- ➔ Maximum availability and therefore minimum downtime due to unscheduled maintenance.
- ➔ Minimal to no disturbance to other key components in the plant (pump and membranes), while keeping under control:
  - Salinity increase and related pressure variation at the inlet of the membranes
  - Flow/Pressure conditions of the inlets and outlets of the ERD system
- ➔ Ease of service.

PX™ Technology Overview

➔ The PX™ Pressure Exchanger™ Technology

Efficiency, availability and durability are the most important features when comparing energy recovery technologies for energy intensive SWRO plants. In a SWRO system equipped with a modular technology such as ERI's PX devices, the membrane reject is directed to the membrane feed as illustrated in Figure 1 below. A free spinning rotor, the only moving part, driven only by flow and moving between the high-pressure and low low-pressure stream, displaces the brine and typically replaces it with an equal volume of seawater. Pressure transfers directly and very efficiently from the high-pressure membrane reject stream to a low-pressure seawater feed stream without a physical piston in the flow path. The devices consist of few parts made of highly durable ceramic materials (alumina), including one moving rotor enclosed with a pair of sealing end-covers. With just one moving part as opposed to piston-type isobaric devices which can include up to 30 moving parts, the PX device design offers premium performance advantages, including high constant efficiencies with simplicity and reliability. .

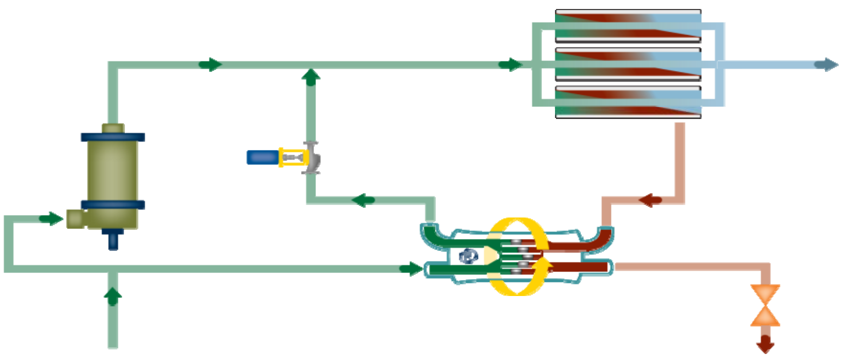

FIGURE 1. Typical SWRO PX™ Device – Equipped System

Because SWRO applications are very demanding, combining corrosive and abrasive conditions with cavitation energy, the materials that make up an ERD also play an important role in the performance and overall reliability and uptime of a plant. PX devices are composed of highly reliable alumina (ceramic) material which is critical to long term and trouble-free seawater reverse osmosis desalination processes.

➔ Designed for a Lifetime: The Next Generation of PX Technology

ERI continues to innovate and improve on the design of the PX devices with the release of the PX-Q300 model. ERI has developed a proprietary ceramic formulation which increases the strength, durability, and performance of the device. ERI continues to push the design envelope of its technology and has incrementally decreased the volumetric and frictional losses resulting in an efficiency increase of approximately 1% at normalized flow when compared to the PX-260 model. **The PX-Q300 device provides exceptional performance, a design life of no less than 25 years and quieter operations at below 81 decibels. Most importantly, the new ERI PX-Q300 offers a 97.2% minimum warranted efficiency – the highest in the industry.**

The improved materials, also allow ERI to provide a device with an industry leading warranty and a design life of 25 years, with quieter operations at below 81 decibels.

➔ Testing for High Efficiencies

Standardized Efficiency Tests

To analyse design and process capability, a standardized efficiency test is required. A standardized test protocol allows comparison between devices built over time, as well as devices of different designs. The standardized efficiency test is conducted under conditions of balanced flow, 1000psi pressure and the nominal rated flow for the PX model under test.

PX devices operate over a wide range of pressure and flow conditions. This flexibility to self-regulate and adapt to system conditions with no external control is an important factor contributing to the long term reliability and ease of use of a PX device. All PX devices are factory tested at multiple operating points. However, for comparison purposes, a single operating point that can be applied to any PX device is required.

Isobaric PX Device Efficiency

ERI Pressure Exchanger models PX-220 and PX-260 represent the majority of the installed base of PX devices. The PX-220 and PX-260 devices utilize ERI's original isobaric design that provides a single pressure exchange per rotor duct per revolution. Together these two models accommodate flow rates from 180gpm to 260gpm. All PX-220 and PX-260 devices undergo performance testing and pass strict acceptance criteria prior to shipping. Historical data is kept in ERI's test database.

PICTURE 1. A Photo of the PX-220 Energy Recovery Device

Charts and Tables below show the measured efficiency of approximately 2,000 PX-220 and 260 devices manufactured over 18 months. **The devices examined validate a minimum efficiency of 96.8%.**

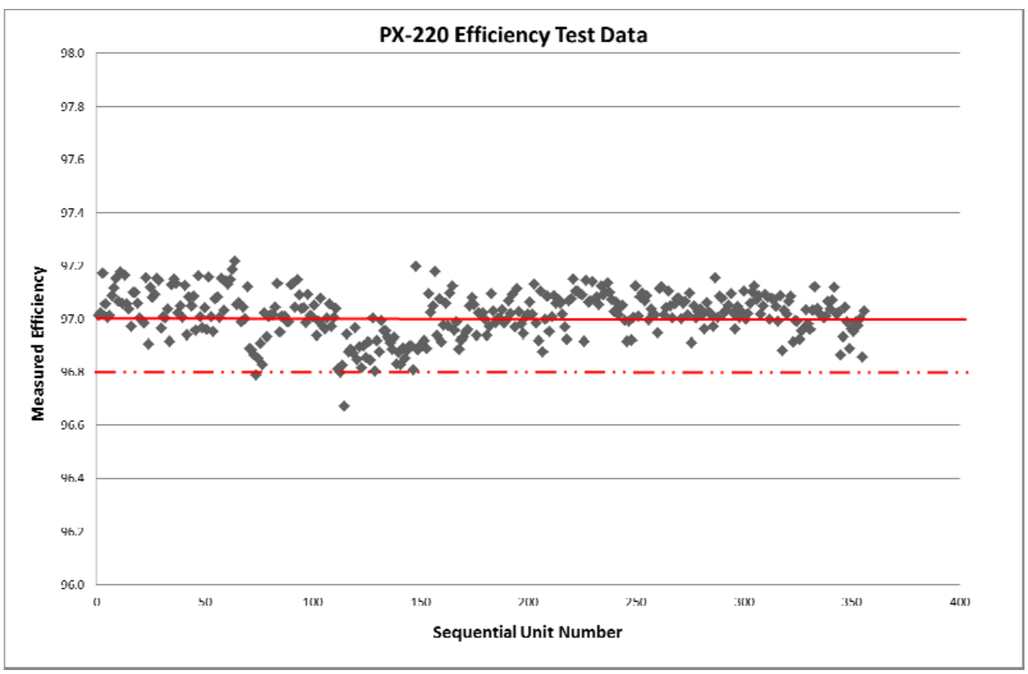

Chart 1. PX-220 Device Efficiencies

PX-220 Energy Recovery Device		
Max Tested Efficiency	97.217%	
Average Tested Efficiency	97.015%	
Minimum Tested Efficiency	96.670%	
Standard Deviation (σ)	0.085%	
	Low Limit	High Limit
1σ limits	96.930%	97.100%
2σ limits	96.845%	97.185%
3σ limits	96.760%	97.270%
Minimum Acceptance	96.800%	

TABLE 1.PX-220 Tested Efficiencies

PX-260 Energy Recovery Device		
Max Tested Efficiency	97.825%	
Average Tested Efficiency	97.019%	
Minimum Tested Efficiency	96.570%	
Standard Deviation (σ)	0.091%	
	Low Limit	High Limit
1σ limits	96.929%	97.110%
2σ limits	96.838%	97.201%
3σ limits	96.747%	97.292%
Minimum Acceptance	96.800%	

TABLE 2.PX-260 Tested Efficiencies

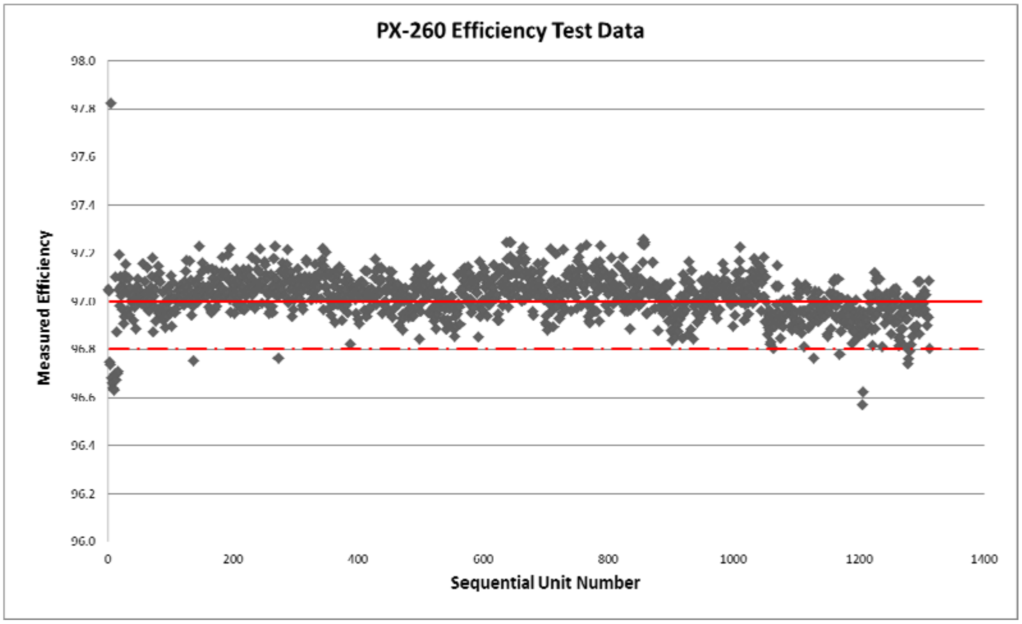

CHART 2.PX-260 Tested Efficiencies

The PX-220 and PX-260 models share a similar base design with modifications to tailor performance to a specific flow range. Therefore, it is not surprising that the data sets are nearly identical. The units were tested for nominal flow at 1000psi to replicate expected field efficiency.

The average efficiency of the tested models (PX-220, PX-260) devices is just over 97% with actual values of 97.015%, and 97.019% respectively. The standard deviation (σ), a measure of variation around the average for the entire data set, is very low at approximately 0.09%. **This shows that performance of the PX 220 and PX260 model is highly consistent from device to device and stable over time.** The stability of the PX devices' design and manufacturing process allow ERI to establish accurate acceptance limits and performance warranties.

The stable process and small standard deviation (σ) allow ERI to set acceptance limits based on statistical analysis of performance. Acceptance limits have been set at a deviation level slightly tighter than 3σ. Statistically, at 3σ limits, 99.7% of the devices produced will be acceptable and only 0.3% will fall outside and will be rejected. However, in this case there is only a lower limit so the resulting defect rate drops to 0.15%.

Minimum acceptable efficiency for PX-220 and PX-260 is 96.8% based on the standardized efficiency test. The actual efficiency of PX-220 and PX-260 devices shipped can be understood by looking at the +/- 1σ, 2σ, and 3σ statistical limits as shown in Table 1 and Table 2. 68.3% of the PX devices actually shipped fall within the +/- 1σ limits, 95.5% within the +/- 2σ limits and 99.7% fall within the +/- 3σ limits**. The production acceptance criteria of 96.8% efficiency is tighter than -3σ.**

Efficiency of a PX device varies with the flow rate. The standardized efficiency test measures efficiency at nominal flow, a reasonable point because typical design flows for PX devices are near nominal flow. The range of flow rates accommodated by the PX device allows it to adjust to variations in system operating conditions. The variation in efficiency for the PX-220 and PX-260 is approximately +0.4% at minimum flow and -0.4% at maximum flow.

ERI Quadribaric™ Device Efficiency

The ERI Pressure Exchanger model PX-300 uses ERI Quadribaric™ technology. The Quadribaric design enables two pressure exchanges per rotor duct per revolution for a more efficient flow path. The PX-300 unit covers a wide range of flow rates from 200 gpm to 300 gpm. The chart and table below discusses the actual lab test on every PX-300 unit shipped by ERI.

The average efficiency for the PX-300device is over 97%. The standard deviation (σ) of the PX-300 device as shown in Table 3 is very low at approximately 0.11%. This shows that the PX-300 device performance is highly consistent from device to device and stable over time. Similar to the PX-220 and PX-260 isobaric designs, the stability of the PX devices' design allow ERI to establish accurate acceptance limits and performance warranties..

Efficiency of the Quadribaric technology, similar to previous PX devices, varies with the flow rate. The standardized efficiency test measures efficiency at nominal flow, a reasonable point because typical design flows for PX devices are near nominal flow. The range of flow rates accommodated by the PX device allows it to adjust to variations in system operating conditions. The variation in efficiency for the PX-300 is approximately +0.6% at minimum flow and -0.8% at maximum flow.

PICTURE 2. A Photo of the PX-300 Energy Recovery Device

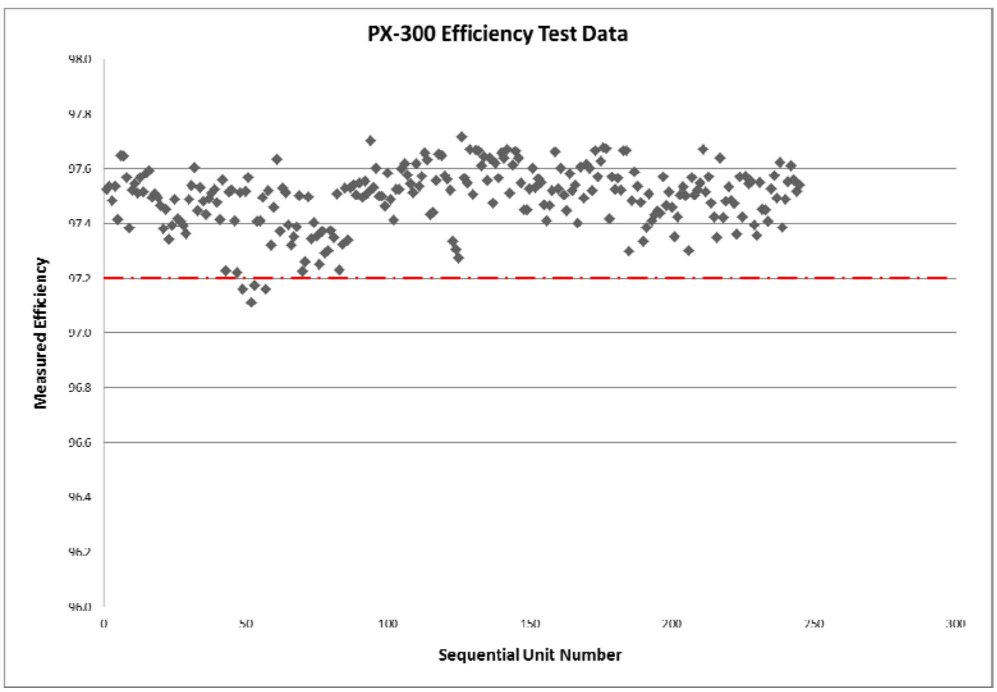

CHART 3. Quadribaric PX-300 Tested Efficiencies

PX-300 Energy Recovery Device		
Max Tested Efficiency	97.716%	
Average Tested Efficiency	97.494%	
Minimum Tested Efficiency	96.110%	
Standard Deviation (σ)	0.111%	
	Low Limit	High Limit
1σ limits	97.383%	97.605%
2σ limits	97.272%	97.716%
3σ limits	97.161%	97.827%
Minimum Acceptance	96.800%	

TABLE 3.PX-300 Tested Efficiencies

What does this mean for future PX devices and efficiency performance?

As test data illustrates, similar PX designs render similar if not identical efficiency results. For example, the PX 220 and PX 260 models were built with the same engineering design years apart- and both show almost identical efficiency test data – an average of 97% efficiency with minute variances. The performance of the newer Quadribaric technology used in the existing PX-300 device indicates efficiency improvements from previous PX models. Therefore, future PX models using the same Quadribaric engineering design are expected to deliver the same minimum, high efficiency.

Recently developed, next generation Quadribaric technology PX devices have shown significant improvements in efficiency. The newest device in the PX family of products, the PX-Q300 device is the most advanced energy recovery device to date. The PX-Q300 technology offers several significant benefits, including but not limited to higher efficiency and durability with quieter operations below 81 decibels. ***In fact, the PX-Q300 will provide plant owners and operators with a guaranteed efficiency of 97.2% - an advantage compared to other competing isobaric devices.***

Summary

ERD efficiency for isobaric rotary devices, such as the PX Pressure Exchanger technology is the highest in its class with averages at or above 97% efficiency. Backed by detailed statistical data and a standardized efficiency test, ERI has been able to quantify specific device efficiency and provide a common data point to measure performance.

The warranted efficiency of PX-220, PX-260 and PX-300 devices is 96.8 %.

Quadribaric technology performance used in the existing PX-300 device indicates efficiency improvements on previous PX models.

100% of all PX devices produced undergo the standardized efficiency test giving ERI the largest product performance database in the industry. Statistical analysis of this large set of data allows ERI to accurately quantify PX device performance and set warranted performance levels. All data lies within a narrow performance range shown by very low standard deviation values. The low standard deviation and a testing time frame of 18 months demonstrate that the PX device design and performance characteristics are predictable and highly stable. This translates to outstanding performance in models that have been in operation for many years. The efficiency of these devices will remain high throughout the life of the system – with a design life to last at least 25 years.

Using ERI's Quadribaric™ technology, the new PX-Q300 device offers higher efficiencies. The guaranteed efficiency for the latest technology is 97.2%.

Many ERDs on the market claim to have high efficiencies, however only warranted efficiencies can guarantee exceptional performance. High performance plants need to also consider other critical factors, including maximum availability no unplanned downtime and the durability of the technologies. A 25 year investment should offer a quick return on the overall economics of a plant.

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More Information

For the latest information about our product and services, please see the following resources:

Websites

www.energyrecovery.com

http://www.watercorporation.com.au/

Whitepapers

1. The Availability Advantage of Reliable Energy Recovery Technologies, Energy Recovery Inc. September 2011.

2. Lifetime Durability of Ceramic PX™ Energy Recovery Devices, Energy Recovery Inc. September 2011.

3. A Five Year Lifecycle Analysis of the Perth Desalination Plant, Clemente, Rodney, IDA World Congress Proceedings, Perth, Australia, September 2011.

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Doc No. 0004-WP-3-83111