INSTALLATION, OPERATION, AND MAINTENANCE MANUAL

LOW-PRESSURE PRESSURE EXCHANGER®
PX L140, L180, L220, L260

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TABLE OF CONTENTS

INTRODUCTION

This manual contains instructions for the installation, operation, and service of the Energy Recovery, Inc. (ERII) Low-Pressure (LP) Pressure Exchanger® (PX) energy recovery devices in brackish water reverse osmosis (BWRO) systems. This information is provided to ensure the long life and safe operation of your PX energy recovery device. Please read this manual thoroughly before installation and operation, and keep it for future reference. This manual is intended for use by personnel with training and experience in the operation and maintenance of fluid handling systems.

1. SAFETY

The Low-Pressure PX energy recovery device is designed to provide safe and reliable service. However, it is a rotating industrial machine that typically operates at high pressure. Operations and maintenance personnel must exercise prudence and proper safety practices to prevent injury and to avoid damaging the equipment and surrounding areas. Use of this manual does not relieve operation and maintenance personnel of the responsibility of applying normal good judgment in the operation and care of this product and its components. The safety officer at the location where this equipment is installed must implement a safety program based on a thorough analysis of local industrial hazards. Proper installation and care of shutdown devices and over-pressure and over-flow protection equipment must be an essential part of any such program. In general, all personnel must be guided by all the basic rules of safety associated with high-pressure equipment and processes. Operation under conditions outside of those stated in Table 3-1 is unsafe and can result in damage to the PX device.

NOTE	These flags denote highlighted items.
CAUTION	These flags denote items that, if not strictly observed, can result in damage or destruction to equipment.
DANGER	These flags denote items that, if not strictly observed, can result in serious injury to personnel.

The flags shown and defined above are used throughout this manual. They should be given special attention when they appear in the text.

NOTE

ERII will not be liable for any project delay, damage or injury caused by the failure to comply with the procedures in this manual. This product must never be operated at flow rates, pressures or temperatures outside of those stated in Table 3-1 or used with liquids not approved by ERII.

2. DESIGN CONSIDERATIONS

2.1 How The PX Energy Recovery Device Works

The Low-Pressure PX energy recovery device facilitates pressure transfer from the high-pressure brine reject stream to a low-pressure process water feed stream. It does this by putting the streams in direct, momentary contact in the ducts of a rotor. The rotor is fit into a ceramic sleeve between two ceramic end covers with precise clearances that, when filled with high-pressure water, create an almost frictionless hydrodynamic bearing. The rotor spinning inside the hydrodynamic bearing is the only moving part in the PX device.

At any given instant, half of the rotor ducts are exposed to the high-pressure (HP) stream and half to the low-pressure (LP) stream. As the rotor turns, the ducts pass a sealing area that separates high and low pressure. Thus, the ducts that contain high pressure are separated from the adjacent ducts containing low pressure by the seal that is formed with the rotor's ribs and the ceramic end covers.

A schematic representation of the ceramic components of the PX energy recovery device is provided in Figure 3-1. Feedwater supplied by the feedwater supply pump flows into a rotor duct on the left side at low pressure. This flow expels brine from the duct on the right side. After the rotor turns past a sealing area, high-pressure brine flows into the right side of the duct, compressing and expelling the feedwater. Pressurized feedwater then flows out to the booster pump. This pressure exchange process is repeated for each duct with every rotation of the rotor, so that the ducts are continuously filling and discharging.

3. FIELD EXPERIENCE[1]

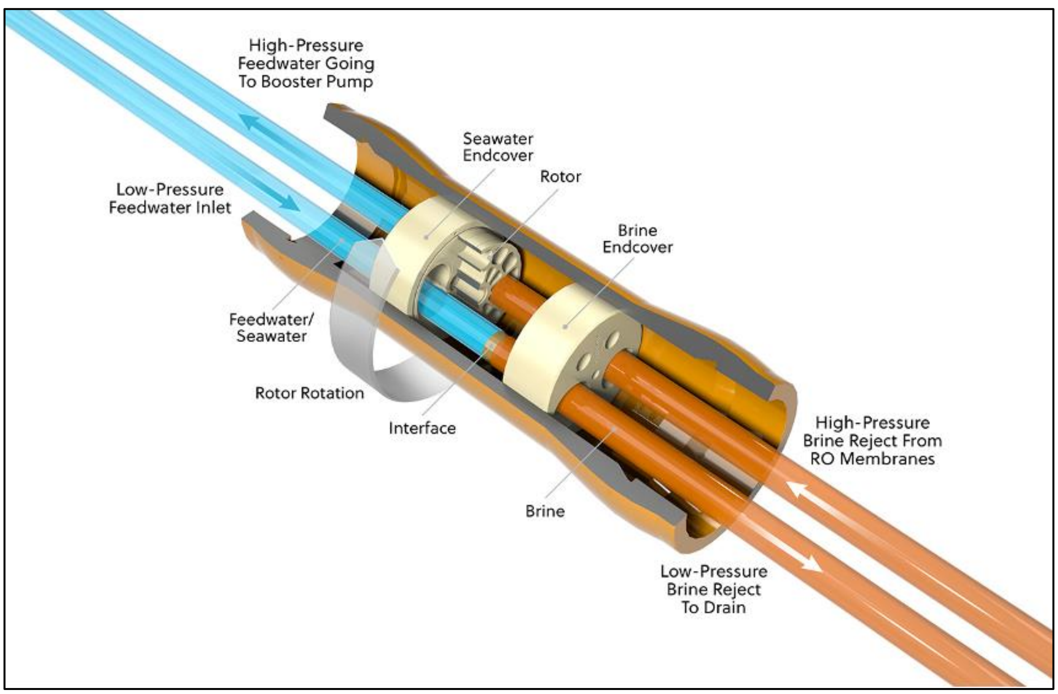

Figure 3-1 Typical Flow Path of a PX Unit

3.1 PX Energy Recovery Devices in BWRO Systems

The PX energy recovery device fundamentally changes the way a BWRO system operates. The issues presented in this and the following sections should be taken into consideration when designing a BWRO system. In addition, engineers at ERII are available for design consultation and review of process and instrument diagrams.

Figure 3-2 illustrates the typical flow path of a PX energy recovery device in a BWRO system. The two-stage BWRO array uses an inter-stage booster pump in the 1st stage reject brine stream [F], to provide pressure boost to increase the net driving pressure in the 2nd stage to balance the flux between each stage. The pressure boost provided by the inter-stage booster pump should be equal or greater than the membrane pressure drop across the stage 1 and stage 2, plus the pressure drop across the high-pressure loop of the PX (HPDP). The reject brine from the BWRO membranes [H] passes through the PX unit, where its pressure is transferred directly to a portion of the incoming raw process water. This pressurized process water stream [D], which is nearly equal in volume and pressure to the brine reject stream, may require pressure throttling to reduce the excess pressure before it merges with the main feedwater to the BWRO system after the main high-pressure pump.

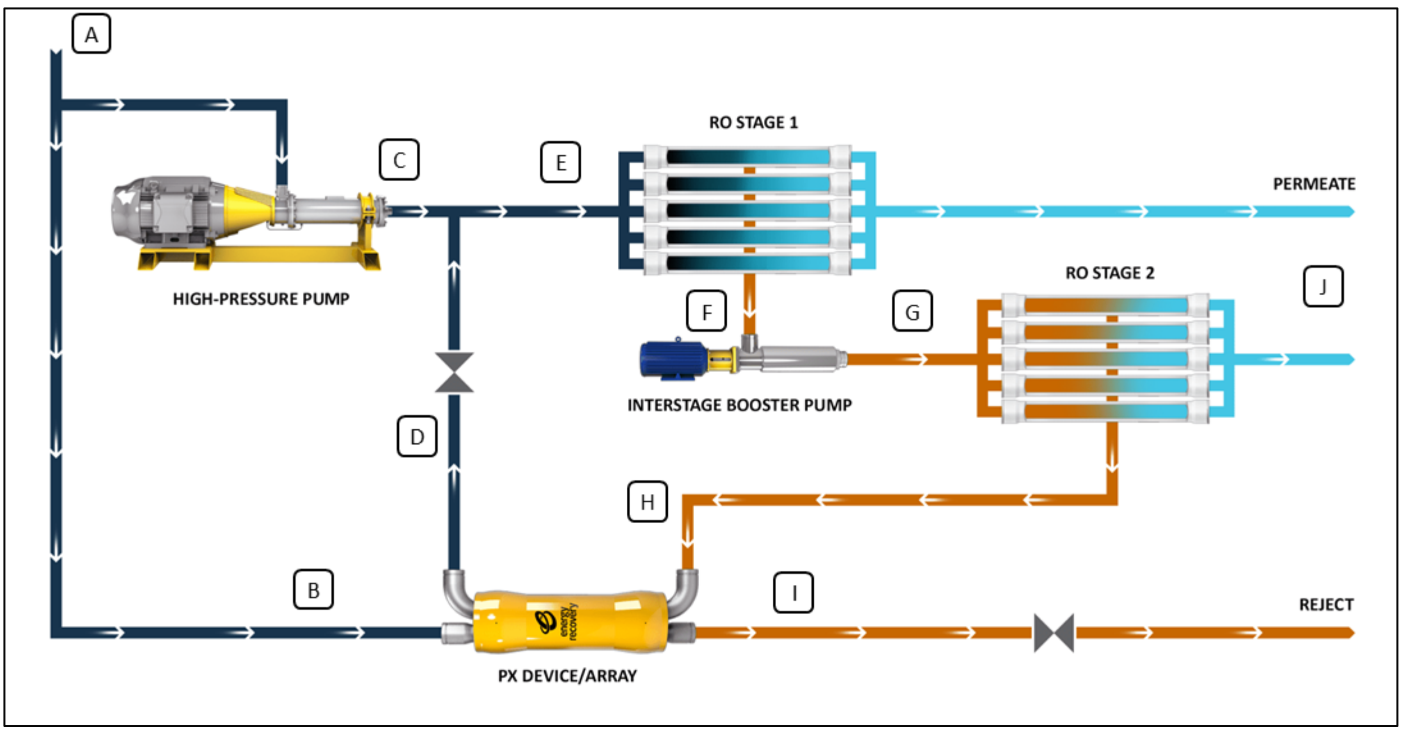

Figure 3-2 Typical Flow Path of a BWRO System with a PX Unit

The flow rate, pressure, and quality of the feed streams to the PX unit must be monitored and controlled. Operation and control of a PX unit in a BWRO system can be understood by visualizing two parallel pipes, one with high-pressure water and one with low-pressure water flowing through the PX unit. With reference to Figure 3-2, the high-pressure water flows in a circuit through the 1st stage membranes, the inter-stage booster pump, the 2nd stage membranes, the PX unit or PX unit array, and back to the membranes (F-G-H-D-E) at a rate controlled by the interaction between the inter-stage booster pump and the flow control valve located downstream of the PX high-pressure outlet stream [D]. The low-pressure water flows from the feedwater supply pump through the PX unit or PX unit array to the system discharge (A-B-I) at a rate controlled by the supply pump and a throttle valve in the brine discharge from the PX unit or PX unit array (I). Since the high- and low-pressure flows are independent, the BWRO plant must be designed for monitoring and control of the flow rates of both streams.

Sample flow rates and pressures for a BWRO system with one PX L260 are listed in Table 3-1 below, with reference to Figure 3-2. In a BWRO system with an ERII device installed, the high-pressure (HP) pump is sized to equal the BWRO permeate flow plus a small amount of bearing lubrication flow, not the full BWRO feed flow. Therefore, PX energy recovery technology significantly reduces flow through the main HP pump. This point is significant because a reduction in the size of the main HP pump results in lower capital and operating costs.

Table 3-1 Typical BWRO System Flows and Pressures

Stream	Description	Flow Rate GPM / m^3/hr	Pressure PSI / Bar
A	Feedwater Supply	1000 / 227	18 / 1.2
B	PX LP IN / Feedwater	245 / 56	18 / 1.2
C	Main HP Pump outlet	755 / 171	175 / 12
D	PX HP OUT / Feedwater	245 / 56	175 / 12
E	RO Feed Stream	1000 / 227	175 / 12
F	First Stage Reject	500 / 114	155 / 11
G	Second Stage Feed	500 / 114	210 / 14
H	PX HP IN / Second Stage Reject	250 / 57	190 / 13
I	PX LP OUT / Second Stage Reject	250 / 57	14.5 / 1.0
J	RO System Permeate	750 / 170	-

3.2 PX Energy Recovery Device Performance

There are no direct controls on a PX device. The rotor is turned by the flow at a rotation rate that is proportional to the flow rate. Therefore, the flow rate, pressure, and quality of the feed streams to the PX unit must be monitored and controlled.

Low-Pressure PX device performance data for a range of flow and pressure conditions is provided on ERII's website. The following data are given in the form of performance curves:

- Efficiency as a function of flow rate
- High- and low-pressure pressure drop as a function of flow rate
- Lubrication flow as a function of pressure

3.3 The Inter-Stage Booster Pump

In the typical BWRO system illustrated in Figure 3-2, an inter-stage booster pump is commonly used to add pressure boost to the concentrate stream of the first stage membranes, in order to provide higher net driving pressure (NPD) to the second stage membranes. The required pressure boost should be enough to compensate for friction losses across both stages of the membranes, the PX unit, and the associated piping. The flow and pressure supplied by the inter-stage booster pump must be controlled with a variable frequency drive or control valve due to the interaction between the inter-stage booster pump; the HP flow control valve located in the PX HP OUTLET stream controls the high-pressure flow rate through the PX unit. Recommended practice is to use a slightly oversized booster pump to handle projected reverse osmosis (RO) membrane flows, taking into account seasonal variations, membrane fouling, and manifold losses.

3.4 Control of Feed Flow, Pressure, and Water Quality

Special consideration should be given to flow and pressure control of the feedwater supply. As mentioned, a throttle valve in the brine discharge from the PX unit can be used to control low- pressure flow through the PX unit(s). Once this valve is set, flow will remain constant as long as the feed pressure does not change. However, if the feed pressure changes, the low-pressure (LP) flow through the PX unit will change accordingly. As long as the maximum allowable feed flow to the PX unit is never exceeded, the PX unit will automatically adjust to small pressure and flow variations. Momentary feed pressure increases can result in flow spikes that could overflow and damage the PX unit.

Pressure/flow spikes require particular consideration in systems with multiple BWRO trains as trains go on- and off-line. An automatic flow control system is not typically responsive enough to provide constant flow during sudden pressure changes. Momentary feed pressure increases can result in flow spikes that could overflow and damage the PX unit. Emergency shutdown sequences should include shutting down the feedwater supply pump(s) to avoid overflow. If large low pressure spikes and overflow cannot be avoided, a pressure regulator and/or relief valve should be installed upstream of the PX units to help stabilize flow. Where feasible, ERII recommends incorporation of a high-flow alarm on the process water supply. ERII will provide specific flow control equipment and instrument recommendations upon request.

CAUTION

Do not exceed the maximum allowable feed flow rate to the PX unit. This may damage the PX device.

Air in the feed streams to the PX unit can damage the device. All air must be purged from both the low- and high-pressure circuits before the system is BWRO pressurized. If the BWRO system will be started automatically, allow sufficient time in the startup sequence so that air may be purged from the system before the HP pump is started.

3.5 Fresh Water Flushing

The BWRO system should include provisions for flushing the PX energy recovery device with fresh water. Flushing is necessary to prevent biological growth in the PX unit during prolonged shutdowns. Biological growth can cause the PX unit’s rotor to stick upon start-up. See Section 6.2 for detailed startup and shutdown procedures.

CAUTION

Failing to flush the PX unit with fresh water before extended shutdowns may result in excessive biological growth that may foul the PX unit and inhibit rotation upon start-up.

3.6 Debris and Initial Flushing

Prior to initial start-up, all piping associated with the PX energy recovery device should be thoroughly flushed to assure that no debris enters and/or damages the PX unit. ERII recommends installation of basket strainers at both inlets to the PX device or PX device array. Basket strainers protect the PX unit(s) from damage caused by debris coming from upstream failures that sometimes occur as a result of corrosion, worn parts, or filter failures. As an alternative, ERII recommends installation of temporary startup strainers during startup and commissioning activities. ERII can provide a list of strainer vendors upon request.

3.7 High Pressure Remains After Shutdown

The high-pressure section of a BWRO system equipped with a PX energy recovery device can remain pressurized for a long time after shutdown. Pressure decreases as water slowly flows through the hydrodynamic bearing of the PX unit. If more rapid system depressurization during shutdowns is required, the system should be designed with accommodating valves and piping.

CAUTION

If rapid depressurization is desired, a high-pressure bypass valve can be installed at the concentrate outlet of the RO membranes, which can be used to manually and/or automatically relieve the pressure at shutdowns.

3.8 Low Pressure Isolation and Over-Pressurization

If the low-pressure side of the PX energy recovery device is isolated before the high-pressure side is depressurized, there is a risk that the PX unit or the low-pressure piping could be damaged by over-pressurization. High-pressure water continuously flows through the PX device's hydrodynamic bearing to low-pressure regions in the PX unit. To prevent this over-pressurization scenario, appropriate relief valves should be used and procedures implemented to assure that the high-pressure side of the PX unit is depressurized prior to isolation of the low-pressure side.

3.9 Multiple PX Unit Manifold Design

The performance of PX energy recovery devices in arrays is identical to the performance of individual PX units as long as the manifolds are correctly designed. Even flow distribution in a PX unit array can be achieved by using large manifold pipe diameters eliminate manifold constrictions. In a sufficiently large manifold, the pressure drop along the manifold is much less than the pressure drop through a PX unit such that the manifolds serve as constant-pressure reservoirs, regardless of flow orientation. In general, a pressure drop of 1 psi (0.07 bar) or less along the length of the manifold will provide even flow distribution. With a properly designed manifold, the PX units in an array naturally distribute flow evenly.

A sample connection at the low-pressure outlet of each PX unit in a PX unit array can be used to confirm the performance of individual units. Low-pressure sample ports are recommended over high-pressure sample ports because low-cost, corrosion-resistant plastic valves can be used.

When PX devices are operating normally at balanced flow, the salinity of the low-pressure outlet water from each PX unit will be approximately equal to the salinity of the reject water from the membranes. If the PX units are not balanced, the salinity of the low-pressure discharge from the unit will be much lower than the salinity of the reject water from the membranes. If one of the PX units is not functioning properly, the salinity of the low-pressure discharge from the unit will be lower than that of the other units. If a rotor is stuck, the salinity from the stuck unit will be close to the salinity of the feedwater feed.

For systems with large manifolds, double flexible coupling connections should be considered to facilitate alignment of the PX units. These connections are illustrated in Figure 3-4.

NOTE	ERII encourages plant designers and engineers to submit P&IDs for engineering review, especially for large or complex BWRO systems.

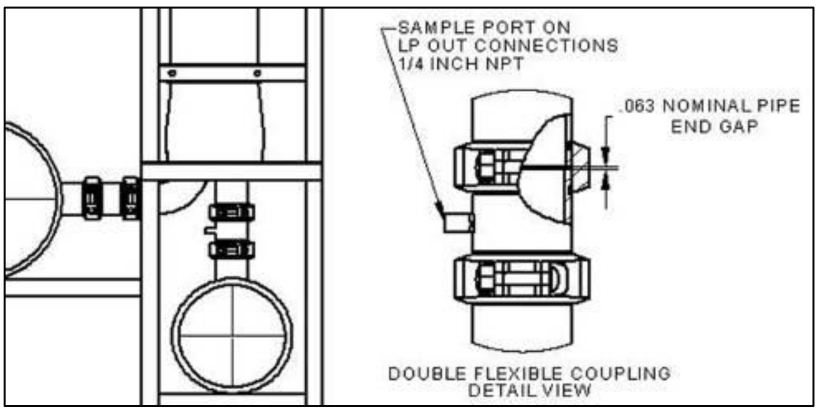

Figure 3-4 Double Coupling Connections for Large Manifolds

4. UNPACKAGING

4.1 Quality & Arrival Inspection

ERII's commitment to quality includes the procurement of top-quality materials and fabrication to extremely tight tolerances. At each stage of the manufacturing process, every part is checked to ensure it meets all dimensional specifications. Assembled PX devices are subjected to extensive testing in our wet test facility. Each PX unit is tested for efficiency, sound levels, operating pressures, and flow rates. Testing records are maintained and each unit is tracked with a serial number. Each PX unit should be inspected immediately upon arrival at a customer's site and any irregularities due to shipment should be reported to the carrier. PX devices are packed in polystyrene foam to protect the unit from damage during transport. The PX unit has been run with a dilute biocide solution to minimize the possibility of biological growth during shipment and storage. The PX unit must never be exposed to temperatures below 33 degrees Fahrenheit (deg F) [1 deg Celsius (C)] or above 120 deg F [49 deg C] during storage or operation.

4.2 Unpacking the Box

1. Open the cardboard box.
2. Remove the protective foam endcap.
3. Carefully lift the Low Pressure out of the box. Keep the protective plastic caps on the port connections until the unit is ready to be installed.
    a. Overhead Lift Machine (fork lift, overhead crane, floor crane) to be used to ensure safe lifting.
    b. Lifting straps can be used around the center of the vessel shown in Figure 4-1.

DANGER	Always use caution when working with heavy objects – The Low-Pressure PX weighs approximately 196 LBS (89 *KG*) – and can be difficult to move and manipulate.
DANGER	DO NOT LIFT USING PORTS. Lift only with lifting straps or slings.

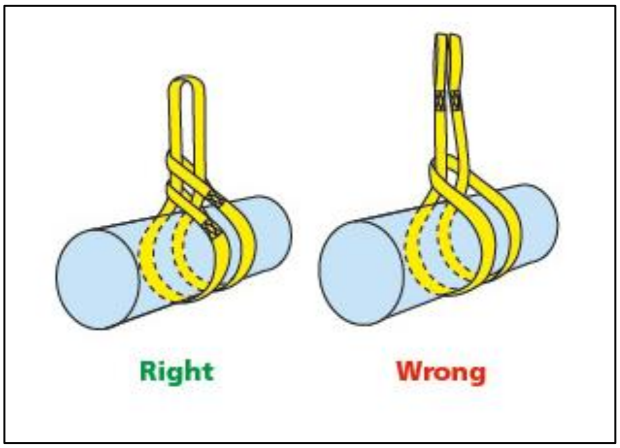

Figure 4-1: Single Sling Double Choker Hitch method

5. INSTALLATION

Low-Pressure PX energy recovery devices can be installed and operated in horizontal, vertical or any other orientation. Each unit has four connections labeled HP IN, HP OUT, LP IN, and LP OUT, see Figure 5-1.

- HP IN is the high-pressure concentrate reject inlet.
- HP OUT is the high-pressure process water outlet.
- LP IN is the low-pressure process water inlet.
- LP OUT is the low-pressure concentrate reject outlet.

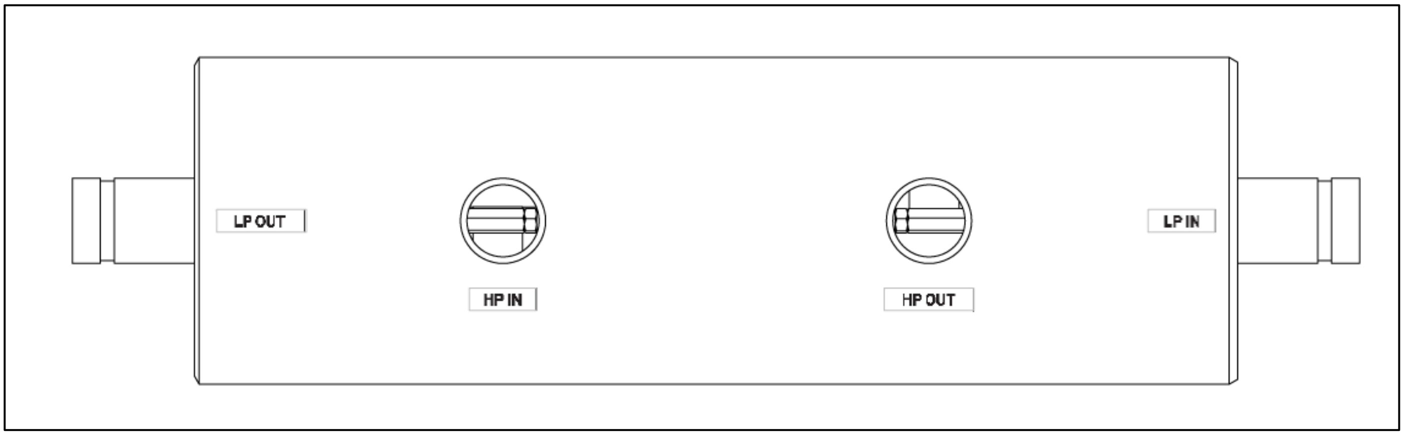

Figure 5-1 Connection Labels

The low-pressure ports and high-pressure ports on housing of the Low-Pressure PX energy recovery device are made of 316 stainless steel or equivalent stainless steel. Proper piping, piping support, and housing support must be employed to minimize external stresses on all pipe fittings. Bearing pads should be used to avoid abrasion of the housing and to act as alignment shims. Flexible couplings should be used for joining fittings and piping. Use only water-soluble lubricants such as glycerin or soap on O-rings and seals. Do not use grease.

DANGER	Do not allow the high-pressure reject feed to the PX unit to exceed 450 psi (31 bar). If necessary, install a pressure switch and/or safety valve in the high-pressure line(s) to ensure that the system does not exceed 450 psi (31 bar).
NOTE	A pressure gauge should be installed near each pipe connection to the PX unit array to facilitate monitoring of PX unit performance.
CAUTION	The PX unit must not be supported by its pipe fittings, nor should the PX unit be allowed to support piping or manifolds. During installation avoid lifting the PX unit by the ports.
DANGER	Thoroughly flush associated piping with water filtered to 10 microns before installing the PX unit. Foreign material may cause damage.

6. OPERATION

6.1 System Performance Specifications, Precautions, and Conditions

Successful operation of the PX Pressure Exchanger energy recovery device requires observation of some basic operating conditions and precautions. The PX unit must be installed, operated, and maintained in accordance with this manual and good industrial practice to ensure safe operation and a long service life. Failure to observe these conditions and precautions can result in damage to the equipment and/or harm to personnel. Table 6-1 provides a summary of system performance limits.

Table 6-1 System Performance Limits

Parameter	Specification	
	English Units	**SI Units**
Maximum high pressure (HP IN or HP OUT)	450 psig	31 bar
Maximum process water inlet pressure (LP IN)	150 psig	10.3 bar
Minimum process water inlet pressure (LP IN)	20 psig	1.4 bar
Minimum brine discharge pressure (LP OUT)(1)	Refer to TDS	
Minimum filtration requirement (nominal)	20 micron	
Process water temperature range	33-120 ºF	1-49 ºC
pH range (Short term at limits)	1-12	
Allowable flow rates (2)	-	
PX L140	90-140 GPM	20-32 m^3/hr
PX L180	100-180 GPM	23-41 m^3/hr
PX L220	150-220 GPM	34-50 m^3/hr
PX L260	180-260 GPM	41-59 m^3/hr

(1) Refer to technical data sheet for minimum required LP OUT pressure.
(2) Unlimited system capacities are achieved by using multiple units in parallel.

DANGER

The ends of the PX assembly must be kept dry and free of corrosion. Deterioration of these segments could lead to failure of the PX unit enclosure. Regular rinsing of the PX unit head assembly with permeate to prevent salt buildup is recommended.

CAUTION

Entrained or trapped air or other gasses must be purged from the BWRO system before pressurization.

CAUTION	Introduction of non-water-soluble contaminants such as grease, oil, wax, petroleum jelly, etc. may inhibit rotor function.
NOTE	The high-pressure pump should never be operated without the circulation pump. An interlock should be installed so that the high-pressure pump will automatically shut down if the circulation pump shuts down.
CAUTION	Do not allow the high-pressure or low-pressure stream flow rates to exceed the flow rates listed in Table 6-1. To comply with the warranty, it is necessary to install flow meters on both the high-pressure stream and low-pressure steams. Failure to do so can result in damage or destruction of the PX unit and/or other equipment.

The following precautions / conditions apply:

- Allowable flow ranges for individual PX units are listed in Table 6-1. PX units are not designed to operate outside of these ranges.
- Feedwater feed to PX units must be filtered to 20 microns or less and should be subjected to the same pretreatment as process water being fed to the BWRO membranes.
- Entrained or trapped air or other gasses must be purged from the BWRO system before pressurization. Large bubbles in a pressurized system can result in damage to piping and equipment, including the PX unit.
- Piping connections to PX units must be designed to minimize stress on the fittings and housing.
- The PX unit vessel end caps incorporate interlocking restraining devices which must be kept dry and free of corrosion. Deterioration of these devices could lead to catastrophic mechanical failure of the PX unit enclosure. The PX unit vessel has weep holes drilled through it near the bearing plates to help keep the vessel heads drained. The vessel heads and weep holes should be regularly flushed with fresh water or permeate to help prevent salt buildup.
- The PX unit must never be exposed to temperatures below 33 deg F [1 deg C] or greater than 120 deg F [49 deg C].
- Under no circumstances shall the brine inlet pressure (HP IN) exceed 450 psig (31 bar).
- The feedwater feed inlet pressure shall not exceed 150 psig (10 bar). For the minimum discharge pressure, refer to the PX unit(s) Technical Data sheet.
- The PX unit(s) must be removed from the BWRO system when performing hydrostatic testing on piping or other BWRO system components. Never attempt to hydrostatically test a PX device.
- Install piping and fittings so that the PX unit(s) can be isolated from membrane reject flow during membrane cleaning. Failure to do so may introduce debris that may damage the PX unit.

6.2 Start and Stop Procedures

The following procedures are general guidelines for the startup and shutdown of PX systems. Procedure details will vary by plant design. Contact ERII if your plant significantly differs from that shown in Figure 3-2. Always ensure that the operating limits listed in Section 6.1 are not violated.

NOTE

A sample operating-log has been provided at the end of Section 10.

6.2.1 System Start Up Sequence

1. All valves should be in their normal operating positions.
2. Start the feedwater supply pump. The feed flow through the PX unit may or may not cause the rotor to begin to rotate. Rotation will produce a humming noise that is audible at close proximity to the PX unit.
3. Adjust the feedwater flow to the desired flow rate.
4. Bleed air from the system.
5. After the PX device has run with feedwater for 5 to 10 minutes, start the inter-stage booster pump at minimum speed and with the flow control valve downstream of the PX fully open. Rotor speed will increase and remaining air will be released from the PX unit. Bleed any remaining air from the system. Adjust the inter-stage pump speed and flow control valve to reach balanced flow and desired inter-stage boost pressure.
6. Adjust the brine flow to balance the high- and low-pressure flows to the PX unit.
7. After the PX unit and booster pump have run for five to ten minutes and all air and gas has been purged from the system, start the main high-pressure pump and adjust the speed of the inter-stage booster pump to achieve the required permeate flow balance. The BWRO system pressure will increase to the point where the permeate flow will equal the flow from the main high-pressure pump. The noise level from the PX unit will increase. Small variations in noise level and rotor speed are normal.
8. Verify that brine reject pressure (LP OUT) exceeds minimum requirements.
9. Verify the high- and low-pressure flow rates. Adjust flows as necessary to achieve balanced flow to the PX unit (LP flowrate with the LP OUT control valve and HP flow rate with the flow control valve located at HPOUT)

6.2.2 Short Term (One to Three Days) System Shutdown Sequence

1. Shut off the main high-pressure pump.
2. Wait until the system pressure drops below 100 psig (7 bar). If necessary, open a purge valve to expedite depressurization.
3. Shut off the inter-stage booster pump.
4. Shut off the feedwater inlet supply pump.

6.2.3 Medium Term (4-14 Days) System Shutdown Sequence

1. Feed the PX unit and BWRO system with fresh water. A feed pressure of 20 psi (1.4 bar) is necessary to assure complete flushing.
2. Make sure inter-stage booster pump is operating. Run the system for 5 to 10 minutes until all the feedwater is purged.
3. Shut off the booster pump.
4. Isolate the freshwater supply source.

NOTE

The high-pressure pump should never be operated without the circulation pump. An interlock should be installed so that the high-pressure pump will automatically shut down if the circulation pump shuts down.

CAUTION

The PX unit must be flushed with fresh water for extended shutdowns to avoid excessive biological growth and precipitation that may foul the PX device and inhibit rotation upon start-up. The high-pressure and low-pressure sides of the PX unit should be flushed separately.

6.2.4 Long Term (More Than Two Weeks) System Shutdown Sequence

If a plant is to be shut down for an extended period of time, the BWRO system including the PX units must be thoroughly flushed with fresh water to remove any salt, and precautions should be taken to inhibit biological growth. The high-pressure and low-pressure sides of the PX unit must be flushed separately. The low-pressure side should be flushed with fresh water through the feedwater feed line to the PX unit and to the brine drain. The high-pressure flush is typically performed by circulating water through the PX unit and the membranes using the booster pump. The PX units should receive a final flush with the same solution used to preserve the BWRO membranes.

CAUTION

Failing to flush the PX unit with fresh water may result in excessive biological growth that may foul the PX unit and inhibit rotation upon start-up. The high-pressure and low-pressure sides of the PX unit must be flushed individually.

6.2.5 Membrane Cleaning

PX unit(s) must be isolated from the reverse osmosis system whenever a chemical cleaning of the membranes is performed to prevent debris from the membrane from entering the PX device. Isolation can be done in a variety of ways, including valves, removable pipe sections, slip blinds (flanges), or removal of the PX units from the system.

CAUTION

PX units must be isolated from the reverse osmosis system whenever a chemical cleaning of the membranes is being performed.

6.3 Flow Control and System Balancing

Flow rates and pressures in a typical BWRO plant will vary slightly over the life of a plant due to temperature variations, membrane fouling, and feed salinity variations. The PX unit's rotor is powered by the flow of fluid through the device. The speed of the rotor is self-adjusting over the PX unit's operating range.

6.3.1 High-Pressure Flow Control

The high-pressure flow through the PX unit is set by adjusting the booster pump with a variable frequency drive or by throttling with a control valve on the booster pump outlet. The flow rate of the high-pressure feedwater out of the PX unit equals the flow rate of the high-pressure brine to the PX unit minus the bearing lubrication flow. The high-pressure flow rate must be verified with a high-pressure flow meter.

NOTE	Recommended practice is to use a slightly oversized booster pump to handle projected BWRO membrane flows, taking into account seasonal variations, membrane fouling, and manifold losses. The flow and pressure of the booster pump can be controlled with a variable frequency drive or a control valve and a flow meter.

CAUTION	The high-pressure flow through the PX unit must never exceed the maximum rated flow rate. The only reliable way to determine this flow rate is to use a high-pressure flow meter.

6.3.2 Low-Pressure Flow Control

The low-pressure flow through the PX unit is controlled by the feedwater supply pump and a throttle valve in the brine discharge from the PX unit(s). This valve also adds backpressure on the PX device required to prevent destructive cavitation. The low-pressure flow rate must be verified with a flow meter. The flow rate of the low-pressure brine from the PX unit equals the flow rate of the low-pressure feedwater to the PX unit plus the bearing lubrication flow rate.

CAUTION	The low-pressure flow through the PX unit must never exceed the maximum rated flow. The only definite way to determine this flow rate is to use a flow meter inthe low-pressure line to or from the PX unit.

6.3.3 Balancing the PX Energy Recovery Device

To achieve balanced flow through the PX energy recovery device, use flow meters installed in the low- and high-pressure lines. The high- and low-pressure brine should be set to equal flow rates to within 5% for optimum BWRO operation. Similarly, the high- and low-pressure feedwater flows should be set to equal flow rates to within 5%. If any doubt exists in reading the flow meter, see Section below.

Operating the PX unit with unbalanced flows can result in contamination of the feedwater feed by the brine reject. The PX device is designed to operate at fluid mixing levels at or below six percent. Balanced flows help limit the mixing of concentrate with the feed. A feedwater inlet flow that is much less than the feedwater outlet will result in lower quality permeate, increased feed pressure, and higher energy consumption.

The following procedure should be applied to achieve balanced flows:

1. Determine the desired flow rate of high-pressure process water from the PX unit.
2. Adjust the feedwater supply rate (or the throttle valve on the low-pressure reject from the PX unit) until the low-pressure feedwater inlet flow rate equals the high-pressure feedwater outlet flow.
3. Adjust the variable frequency drive on the booster pump or the high-pressure control valve until the desired flow rate is achieved as indicated by the high-pressure flow meter.

6.3.5 Measurement of PX Device Lubrication Flow Rate

In a PX energy recovery device, some of the high-pressure water flows through the hydrodynamic bearing to low-pressure regions in the assembly. The lubrication flow rate varies with system pressure according to performance curves available on ERII's Website. If the PX device is damaged by debris, overflow or insufficient discharge pressure, excess lubrication flow may occur. Inversely, monitoring lubrication flow is a good way to check the integrity of an operating PX unit. Lubrication flow can be determined using any of the following three methods:

1. Measure the flow rate of the low-pressure process water to the high-pressure pump and the flow rate of the permeate. The difference is the lubrication flow rate.
2. Measure the flow rate of the high-pressure brine to the PX unit and the high-pressure process water from the PX unit. The difference is the lubrication flow rate.
3. Measure the flow rate of the low-pressure brine from the PX unit and the low-pressure process water to the PX unit. The difference is the lubrication flow rate.

7. SPARE PARTS AND TOOL KITS

The PX Pressure Exchanger energy recovery device needs no scheduled periodic maintenance. However, in the event that the PX unit is disassembled, ERII recommends use of the following:

- PX L Series Tool Kit – ERII Part Number 20486-01
- PX L Series Spares Kit – ERII Part Number 20487-01

Replacements for other components in the PX assembly are available. Refer to assembly drawing for PX component names, part numbers and the bill of materials for the PX assembly.

The PX unit is designed so that it can be assembled and disassembled in the field with only basic tools and equipment. If the PX unit must be assembled or disassembled, the tools and fixtures listed in Table 7-1 are required. Figure 7-1 shows how to fabricate a stand for the PX unit for inspection or maintenance. Alternately, blocks with similar dimensions may be used.

Table 7-1 Tool Kit 20486-01 Bill of Materials

Part Number	Description	Purpose
20036-01	KIT, TOOL, HEAD PULLER, 8" SERIES, SIDE-PORT	Tool designed to facilitate removal of Head Assembly
30207-01	TOOL, LIFTING STRAP, FABRIC	Attached to the housing to support lifting purposes.
10506-01	NUT, LIFTING EYE, 5/8"-11, 316	Lifting Eye for cartridge. To be used in conjunction with All Thread found in 20036-01 and Coupling Nut 30092-01.
30092-01	NUT, COUPLING, 1/2"-13, TO, 5/8"-11, RED	Couples All Thread found in 20036-01 with Cartridge.

30048-01	TOOL, BAR, HEAD-PULLER	Tool to help remove cartridge with tools 20036-01 and 30092-01.
30100-01	ROD, SPINNING, ROTOR	Rod to help spin the rotor during assembly.
10673-01	WRENCH, ALLEN, TEE, 6MM	Tool to remove socket head cap screws from lock rings.
10137-01	WRENCH, COMBO, 3/4", CARBON STEEL	Tool for Hex Bolts.
10225-01	ANTI-SEIZE, .25 OZ, TUBE, NICKEL, MSDS REQUIRED	Anti-Seize for threaded connections.
10329-01	WRENCH, CRESCENT, 6"	Tool for Hex bolts.
10085-01	NUT, LIFTING EYE, 1/2"-13, 316	Lifting Eye for cartridge

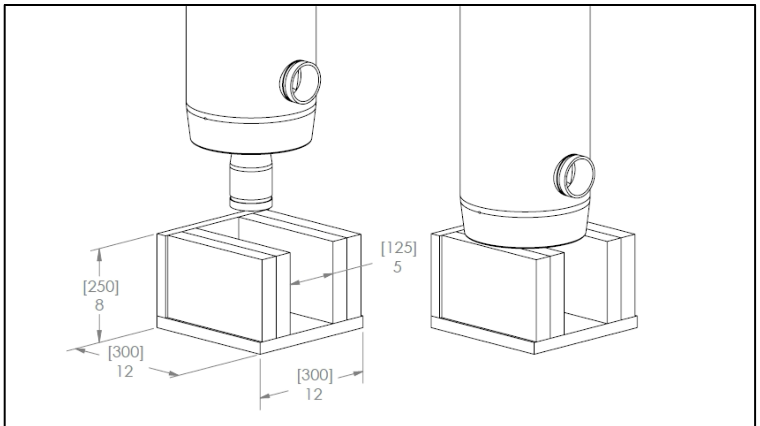

Figure 7-1 PX Device Stand

Replacement seals and pins are included in an ERII spare parts kits (Part Number 20487-01). One spare parts kit should be used each time a PX unit is opened for service.

Replacements for other components in the PX assembly are available.

CAUTION

Metal objects can chip or crack ceramic. Use caution when handling ceramic components to avoid damage.

NOTE

All seals should be replaced each time a PX device is opened for service. Replacement seals and pins are included in spare parts kit, Part Number 20487-01.

8. SERVICE

If the inlet and outlet flows are measured and balanced properly, the process water is filtered and the PX unit is properly flushed before extended shut downs (as described in Section 6.2), the PX unit should operate maintenance- and trouble-free for many years. PX devices need no scheduled periodic maintenance. There are no shafts, couplings, seals, or lubrication systems to maintain or monitor.

If a PX unit must be assembled or disassembled, the procedures provided in this section should be followed carefully. The tools and fixtures listed in Table 7-1 are required. The procedures provided in this subsection are for complete assembly or disassembly of a PX unit. Depending upon the reason for the maintenance work, complete assembly or disassembly may not be required. Refer to Section 7 for recommended spare parts and tool kits. Reference the top-level drawing and bill of material for a complete list of components.

8.1 Disassembly Procedure

The following procedure is for disassembling a Low-Pressure PX energy recovery device to inspect the ceramic components. Refer to Section 7 for a listing of spare parts and tool kits useful for disassembly and reassembly of a PX unit.

CAUTION

When handling and installing a PX unit, do not drop the unit or put undue strain on the port fittings to avoid internal damage. Hoist the PX unit using the lifting eye supplied with the Tool Kit 20486-01.

DANGER

Make sure the system is fully depressurized prior to disconnecting the PX unit.

1. Depressurize all high-pressure and low-pressure piping to and from the PX unit.
2. Close all valves to and from the PX unit.
3. Disconnect all flexible couplings from the high- and low-pressure ports.
4. Remove the PX unit from the system.
5. Stand the PX unit on a PX stand. See Figure 7-1.
6. Remove the three (3) M8 Socket-head screw from LP port plate, as shown in Figure 8-1, using a 6mm Allen wrench.
7. Remove the (3) Lock-ring as shown in Figure 8-1

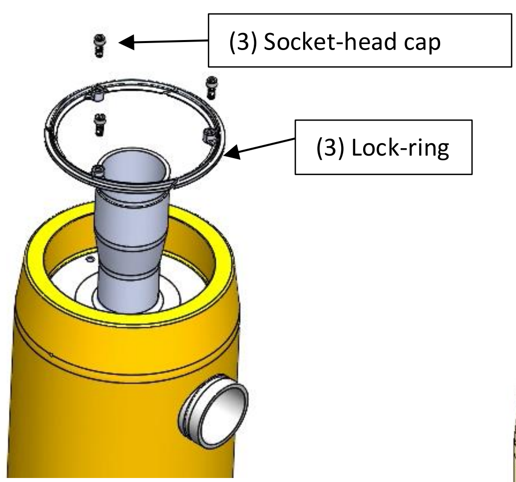

Figure 8-1 Socket-head cap screw and lock ring removal

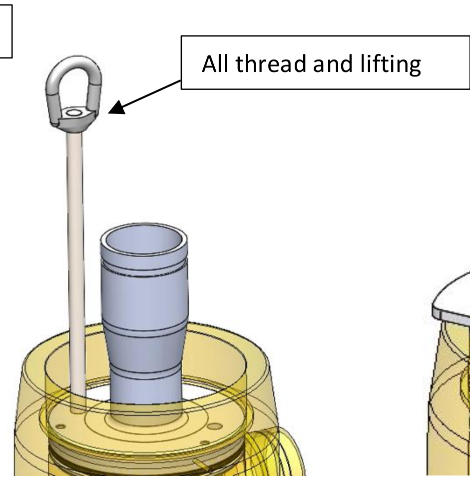

Figure 8-2 Remove head assembly

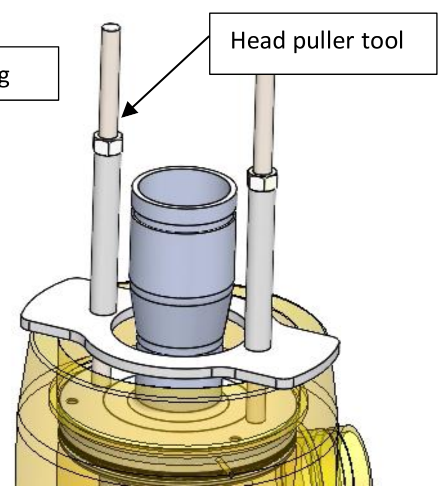

Figure 8-3 Head assembly removal using tool 30082-01

8. Gently tap down on the LP Port to loosen head assembly from housing. Remove head assembly from housing shown in Figure 8-2. Assisted lifting can be achieved using the All-thread and Lifting Eye 5/8-11” as shown in Figure 8-2. If required, use an Energy Recovery Head Puller tool 20036-01 shown in Figure 8-3. Always use a wood block to protect the edge of the housing if force is necessary to remove the head assembly.
9. Extracting the ceramic cartridge assembly:
    a. Attach the lifting tool onto the end of the tension rod. See Figure 8-4. Attach a hoist to the lifting eye.
    b. Clean the inner diameter of housing to remove any salt build up or biofouling present.
    c. Lubricate the inside of the housing with a water-soluble lubricant such as glycerin or nonabrasive liquid soap.
    d. Extract the ceramic rotor subassembly of the housing. It may be necessary to apply downward force to the edge of the housing while hoisting to get the ceramic rotor subassembly to slide out of the housing.

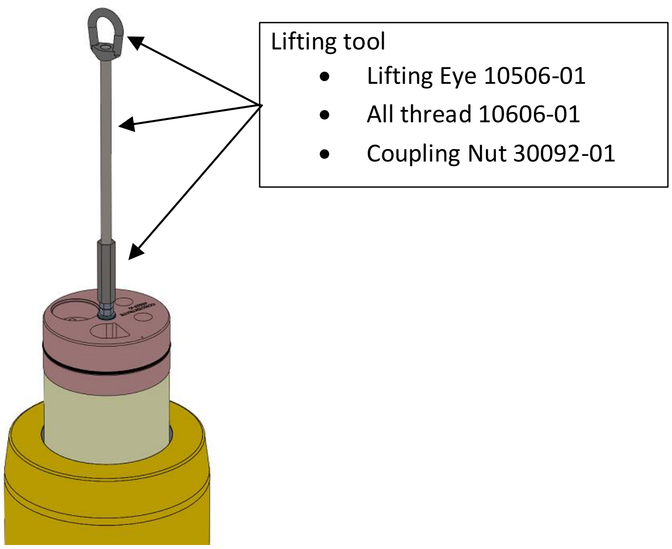

Figure 8-4 Cartridge removal

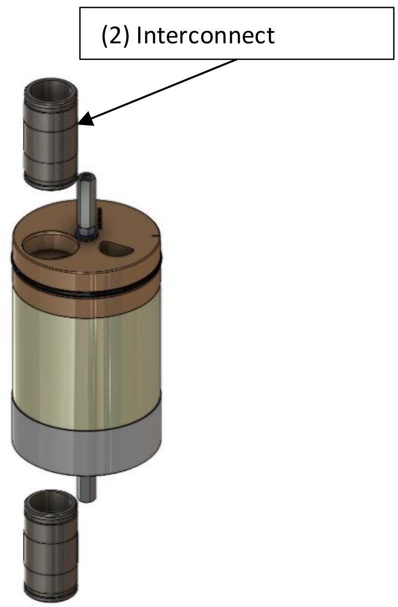

Figure 8-5 Remove (2) Interconnect

10. Gently place the cartridge on a clean surface or towel. Remove two (2) interconnects, see Figure 8-5.
11. The ceramic rotor subassembly must be returned to the housing in the same orientation it was removed. Mark the ceramic cartridge with a pencil or marker to assure that correct orientation is retained upon reassembly. The HP IN Endcover has an O-ring on the outside.
12. Stand the ceramic rotor subassembly on blocks allowing clearance for the tension bolt and nuts on the bottom of the assembly. See Figure 8-6, which illustrates correct rotor subassembly orientation.

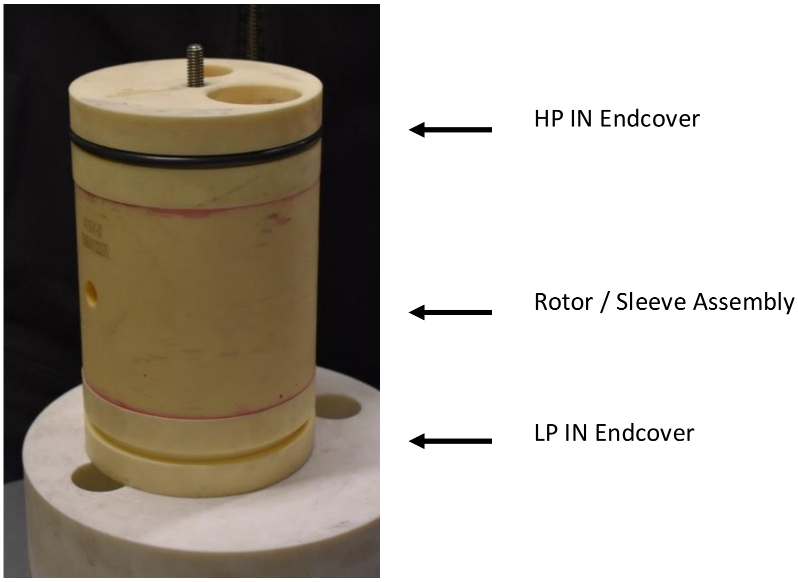

Figure 8-6 Cartridge Assembly

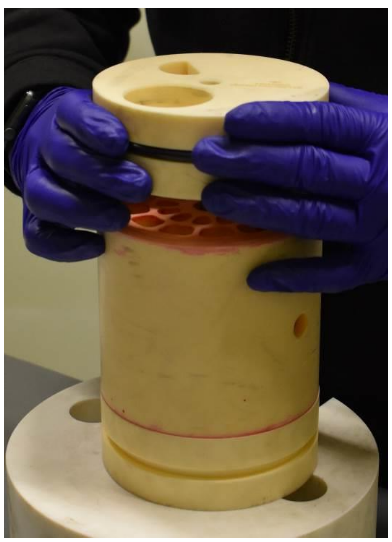

Figure 8-7 – Lifting Endcover

Figure 8-8 Alignment Pins

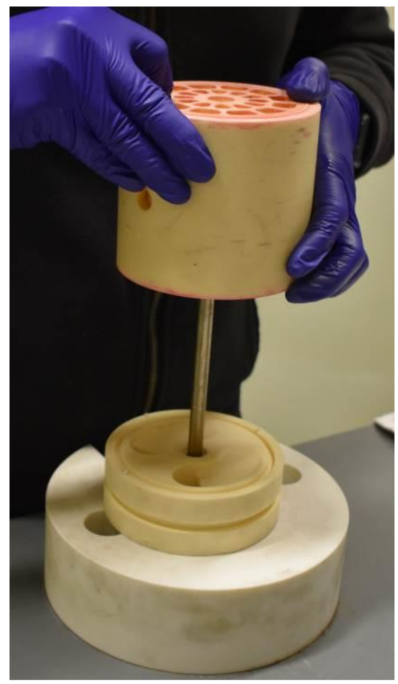

Figure 8-9 Lifting the rotor and sleeve

13. Remove the hex nuts from the top end of the tension rod.
14. Lift the Endcover off the rotor and sleeve, be careful not to lose the alignment pins or replace as required. See Figure 8-7 and Figure 8-8.
15. Lift the rotor and sleeve off the bottom Endcover. See Figure 8-9. DO NOT ALLOW THE ROTOR TO COME OUT OF THE SLEEVE.
16. If the rotor comes out of the sleeve, the following procedure should be applied:
    a. Clean the rotor and sleeve. Rinse liberally.
    b. Inspect rotor and sleeve. Remove all debris. Avoid getting lint or dirt onto the ceramic. Re-rinse if necessary.

c. Identify the end of the rotor marked “CHK”. Place the rotor on a flat clean surface with the end marked “CHK” oriented upward.
d. Identify the end of the sleeve marked “CHK” and orient it upward. The sleeve is marked “CHK SWP” should be oriented downward.
e. Hold the sleeve over the rotor. Slowly slide the sleeve onto the rotor. This is a very tight fit and requires a gentle touch. Do not force the sleeve on by pressing or hitting it. The sleeve should slide on easily. If the rotor and sleeve become bound, use hot water on the sleeve to loosen it from the rotor.
f. Contact ERII if problems are encountered.

CAUTION	Thoroughly flush all PX components with water filtered to 10 microns before assembling PX unit. Foreign material may inhibit rotor movement.

8.2 Assembly Procedure

This assembly procedure assumes that the PX unit has been disassembled per the previous section. All parts should be carefully cleaned with clear water prior to assembly to ensure that no dirt or debris contaminates the PX device. All parts should be thoroughly inspected for damage and/or debris prior to reassembly. O-rings should be replaced by new set of O-rings. Do not attempt to reassemble a PX unit with damaged or broken parts.

Always lubricate all O-ring mating surfaces immediately prior to assembly with a suitable water-soluble lubricant such as glycerin or liquid soap. See Figure 8-10.

NOTE	All seals should be replaced each time a PX device is opened for service. Replacement seals and pins are included in spare parts kit, Part Number 20487-01.

Figure 8-10 O-ring comparison

To assemble the cartridge, follow these steps:

1. Lubricate the tension-rod O-rings and the inside of the center hole of both Endcovers with a water-soluble lubricant such as glycerin or non-abrasive liquid soap. Do not use grease! Introduction of non-water-soluble films such as grease, oil, wax, petroleum jelly, etc. may cause the PX rotor to seize.

2. Insert the tension-rod through one of the ceramic Endcovers. See Figure 8-12.
3. Insert dowel pins into the three (3) holes in the face of one Endcover. See Figure 8-11. Make sure the dowel pins insert fully without binding and without being shaved. If pins bind, remove and clear pins and holes of any debris.
4. Place the rotor and sleeve on the Endcover. Make sure that the dowel pins in the Endcover line up with the three (3) holes in the sleeve. See Figure 8-12.
5. Insert dowel pins into the three (3) holes in the end of the sleeve. Make sure the dowel pins insert fully without binding and without being shaved. If the pins bind, remove and clear pins and holes of any debris. See Figure 8-11.
6. Place the Endcover on the rotor and sleeve. Make sure that the dowel pins in the sleeve line up with the three (3) holes in the Endcover. See Figure 8-12.
7. Carefully inspect the contact lines between the sleeve and the Endcovers to assure that there are no gaps. Occasionally, the assembly process will shave one or more of the pins and the debris that is generated will prevent the sleeve and the Endcover from coming into intimate contact. If this occurs, remove the rotor and sleeve assembly, rinse ceramics and remove all debris. Then repeat assembly.

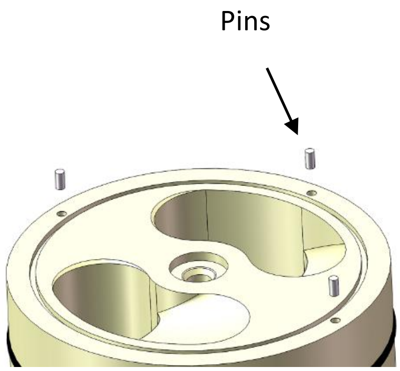

Figure 8-11 Insert dowel pins

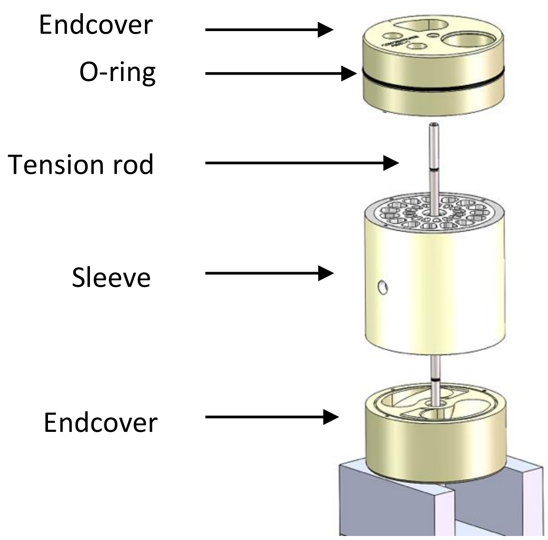

Figure 8-12 Cartridge assembly

CAUTION	Introduction of non-water-soluble films such as grease, oil, wax, petroleum jelly, etc. may inhibit rotor function.

CAUTION	Alignment pins must not bind or be shaved during installation. Carefully inspect ceramic contact lines after installation for any indication of pin damage or binding.

8. Install both washers and one hex nut finger tight. The fiberglass washer should be against the ceramic followed by the metal washer and then the nut. See Figure 8-13.

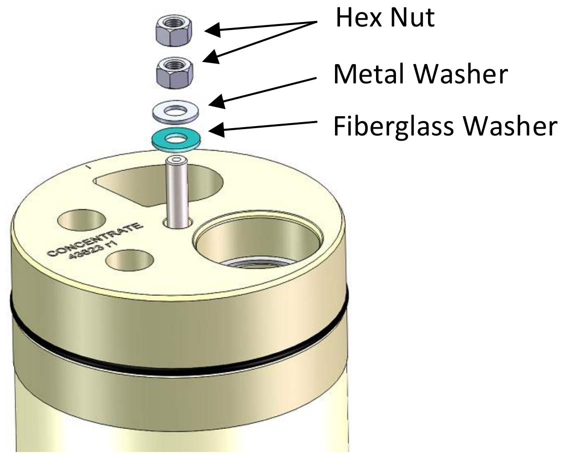

Figure 8-13 Washer sequence

9. Tighten and torque the hex nuts onto ceramic rotor subassembly to 15 ft-lb (20 N-m).
10. Thread the second nut onto the tension rod. This nut will act as a lock nut. Torque to 40 ft-lb (56 N-m) while holding the adjacent nut. Make sure that the tension the inner nuts apply on the cartridge does not change. See Figure 8-14.
11. Repeat step above for the opposite side second nut with torque of 40 ft-lb (56 N-m).
12. Verify both inner nuts (closest to the Endcover) are secured.
13. Verify that the rotor can spin freely. Use a wooden or plastic rod to advance the rotor as illustrated in Figure 8-15. DO NOT USE METAL OBJECT TO SPIN THE ROTOR.

Figure 8-14 Tightening nut

Figure 8-15 Spin rotor

14. Lubricate all O-rings on the Interconnects and counter-bores of the Endcovers. Insert the Interconnects into the counter-bores of the Endcovers. The completed ceramic cartridge assembly is now ready to go into the housing. See Figure 8-16.

Figure 8-16 Completed cartridge

15. Generously lubricate the inside of the housing, the bore in the bearing plate and all O-rings with a water-soluble lubricant.
16. Attach the lifting eye to the ceramic rotor subassembly. Attach a hoist to the lifting eye and hoist the rotor subassembly. See Figure 8-17.
17. Lower the cartridge assembly into the housing. Make sure that the end cap opening is lined up with the Interconnect. See Figure 8-18.

Figure 8-17 Hoist cartridge

Figure 8-18 Lower cartridge

18. Lubricate the interconnect O-ring and counter-bore in the LP port plate. Ensure the interconnect position is aligned with the LP port. Insert the LP port into the housing.
19. Gently tap down on the LP port to ensure the Head Assembly is fully seated
20. Install (3) Lock-rings into groove and (3) M8 Socket-head cap screws.

Figure 8-26 Assemble lock-ring and cap screw

CAUTION	When handling and installing a PX unit, care should be taken to avoid dropping the unit or putting undue strain on the port fittings to avoid internal damage. Do not lift the PX unit with the ports. Use the lifting eye provided with the Tool Kit 20486-01.

9. TROUBLESHOOTING

This section is designed to guide the operator in identifying and correcting most of the problems that could occur in the PX Pressure Exchanger energy recovery device. The instructions provided below are intended for use by personnel with general training and experience in the operation and maintenance of fluid handling systems. This is not intended as a comprehensive maintenance guide. The best troubleshooting tool is the knowledge, experience, and day-to-day observations compiled by the BWRO plant operator. Conditions not covered in this section may be resolved by contacting ERII's Service Department.

Preliminary procedures:

1. Always check for proper valve configuration for the operation mode selected.
2. Always check for loose connections or broken wires when checking electrical parts.
3. Always inspect and test equipment or apparatus for possible causes of malfunctions before performing replacements.

Instrumentation:

The following list of instrumentation is useful in monitoring and diagnosing the operation of PX devices.

- ERII requires that one flowmeter be installed in the PX unit(s) HP flow circuit and one in the LP flow path.
- ERII requires a pressure instrument be installed between the low-pressure outlet and any control valve to monitor device backpressure.

- ERII recommends that high flow and pressure alarms/shutdowns be incorporated into the system design to protect the PX unit(s) from potential damage by high flows.
- ERII suggest using a TDS meter to check the conductivity of the streams entering and exiting the PX device to monitor device performance.

When using this troubleshooting guide, please read all the probable causes before taking any action. Use common sense and select the cause that seems to best fit the given situation.

Table 9-1 Troubleshooting

SYMPTOM	PROBABLE CAUSE	CORRECTIVE ACTION
A. Excessive sound levels	1. Operating PX unit(s) above rated flow rates on low-pressure side, high-pressure side or both	Immediately reduce flow rate by adjustment of circulation pump and LP control valve. Balance the system as described in Section 6.3. To increase system capacity, add PX unit(s) in parallel to existing units.
	2. Operating PX unit(s) below minimum back-pressure	Increase back-pressure by adjusting the LP control valve. Re-balance the system as described in Section 6.3.
	3. Air in system	Bleed air.
	4. PX unit or ceramic cartridge installed upside down	Verify that the PX unit has been installed with the end marked "HP IN" oriented toward the Concentrate inlet. If service was performed, verify the orientation of the ceramic cartridge by removing the Concentrate-side port bearing plate assembly. The Endcover marked "Brine" should be oriented toward the Concentrate inlet/outlet.
	5. Damaged ceramic	Contact the ERII Service Department

SYMPTOM	PROBABLE CAUSE	CORRECTIVE ACTION
B. Excessive high pressure in BWRO system.	1. High-pressure pump is operating at too high a flow rate.	Verify that main HP pump flow rate does not exceed the membrane array production capacity for a given temperature, salinity, and fouling factor.
	2. Excessively high recovery in the BWRO system.	Reduce recovery by increasing and balancing flows through the PX unit(s). Do not exceed recommended maximum PX unit flow rates. To increase capacity, add PX unit(s) in parallel to existing units.
	3. Low-pressure flow is less than high-pressure flow, resulting in mixing and high BWRO feed water salinity.	See Section 6.3
	4. Stuck rotor.	See Symptom D.
C. High salinity in high-pressure process water feed stream	1. Unbalanced system - low-pressure flow rate too low or high-pressure flow rate too high	See Section 6.3.
	2. A jammed or stalled rotor short circuits high-pressure brine reject water with high-pressure feed water. No exchange occurs; no audible rotation.	See Symptom D.
	3. Malfunctioning and/or stalled circulation pump	Check circulation pump's rotation, operation, flows, and pressures.
D. Stalled rotor - no audible rotation	1. Operating system above rated pressure or below rated permeate flow capacity	Check pressures and flows. See Table 6-1
	2. Foreign debris or particles lodged in device.	Contact the ERII Service Department.
E. Low permeate flow	1. Malfunctioning high-pressure pump.	Verify high-pressure pump flow rate and pressure.

SYMPTOM	PROBABLE CAUSE	CORRECTIVE ACTION
	2. High lubrication/leakage flow through PX unit(s)	Leak inside PX unit or stalled rotor. Confirm that all rotors are rotating. If not, see Symptom D. If all rotors are rotating, contact the ERII Service Department.
F. Low brine reject flow	1. Excessive pressure losses through SBWRO system 2. Malfunctioning and/or stalled circulation pump	Contact BWRO supplier. Check circulation pump operation, flows, and pressures.

10. FIELD COMMISSIONING AND SUPPORT SERVICES

The Technical Services staff of ERII offers commissioning service for all ERII products during field installation and/or at a BWRO system manufacturer's location. Although not required, ERII offers commissioning as an additional service for those customers who may find it beneficial. Rate quotes are available upon request.

Should a problem develop with any ERII product, the ERII Technical Services group is prepared to handle customers' concerns whether the location is domestic or abroad.
Service rates are available upon request.

Energy Recovery, Inc.
1717 Doolittle Drive
San Leandro, CA 94577 USA
Email: aftermarketsales@energyrecovery.com
Web: www.energyrecovery.com

ENERGY RECOVERY, INC. SAMPLE OPERATING LOG

NOTE: Daily data must be collected and maintained to support any warranty claims.

Total number of Pressure Exchangers in parallel __________

Model of Pressure Exchanger(s) installed ____

Serial Number(s) ____

Units (please circle one): psi/gpm bar/m^3/hr

Date	Total Hours	HP Inlet Pressure	HP Inlet Flow	HP Inlet Salinity	HP Outlet Pressure	HP Outlet Flow	HP Outlet Salinity	LP Inlet Pressure	LP Inlet Flow	LP Inlet Salinity	LP Outlet Pressure