ENERGY RECOVERY, INC.

INSTALLATION, OPERATION, & MAINTENANCE MANUAL

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ERI™
4S Series Pressure Exchanger™
Energy Recovery Device

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INSTALLATION, OPERATION, & MAINTENANCE MANUAL
ERI 4S SERIES PRESSURE EXCHANGER

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1.0 INTRODUCTION

This manual contains instructions for the installation, operation, and maintenance of the Energy Recovery, Inc.™ ERI™ 4S Series PX Pressure Exchanger™ energy recovery device in sea water reverse osmosis (SWRO) 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. The instructions in this manual are intended for personnel with general training and experience in the operation and maintenance of fluid handling systems.

2.0 SAFETY

The PX Pressure Exchanger energy recovery device is designed to provide safe and reliable service. However, it is both a pressure vessel and a piece of rotating industrial machinery. Therefore, operations and maintenance personnel must exercise good judgment and proper safety practices to avoid damage to the equipment, to avoid damage to surrounding areas, and to prevent injury. It must be understood that the information contained in this manual does not relieve operation and maintenance personnel of the responsibility of exercising 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 establish 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 6-1 can result in damage to the ERI device and must be avoided.

NOTE	Energy Recovery, Inc. 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 6-1, or used with liquids not approved by Energy Recovery, Inc.

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

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

™ Energy Recovery, Inc., ERI, PX, Pressure Exchanger, and PX Pressure Exchanger are trademarks of Energy Recovery, Inc.

3.0 QUALITY & ARRIVAL INSPECTION

Energy Recovery, Inc.'s commitment to quality includes the procurement of top quality materials and fabrication to extremely tight tolerances. Every part is checked to ensure it meets all dimensional specifications at each stage of the manufacturing process. Assembled ERI devices are subjected to extensive testing in our wet test facility. Each PX unit is tested for efficiency, noise 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 Pressure Exchanger devices are packed in polystyrene foam with plugs in the fittings to protect the unit from damage during transportation. 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 less than 33 deg F [1 deg C] or greater than 120 deg F [49 deg C] during storage or operation.

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 or support the PX unit by the port fittings.

4.0 DESIGN CONSIDERATIONS

4.1 How the PX Energy Recovery Device Works

The PX Pressure Exchanger energy recovery device facilitates pressure transfer from the high-pressure brine reject stream to the low-pressure seawater feed stream by putting the streams in direct, momentary contact. The transfer occurs in the ducts of a rotor. The rotor is fit into a ceramic sleeve between two ceramic endcovers with precise clearances that, when filled with high-pressure water, create an almost frictionless hydrodynamic bearing. At any given instant, half of the rotor ducts are exposed to the high-pressure stream and half the ducts are exposed to the low-pressure 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 formed with the rotor's ribs and the ceramic endcovers.

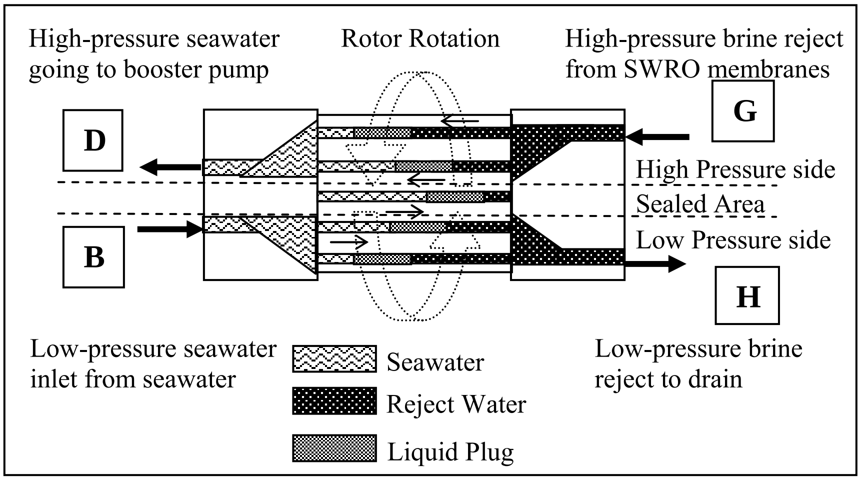
A schematic representation of the ceramic components of the PX energy recovery device is provided in Figure 4-1. Seawater supplied by the seawater supply pump flows into a duct on the left side at low pressure. This flow expels brine from the duct on the right side. After the rotor turns past a sealing area, high-pressure brine flows into the right side of the duct, pressurizing the seawater. Pressurized seawater then flows out to the booster pump. This pressure exchange process is repeated for each duct with every rotation of the rotor such that the ducts are continuously filling and discharging. At a nominal speed of 1,200 rpm, 20 revolutions are completed every second.

NOTE

The PX unit and associated boost pump are sized for the membrane reject flow. The capacity of the main high-pressure pump is equal to the permeate flow rate plus the hydrodynamic bearing lubrication flow rate.

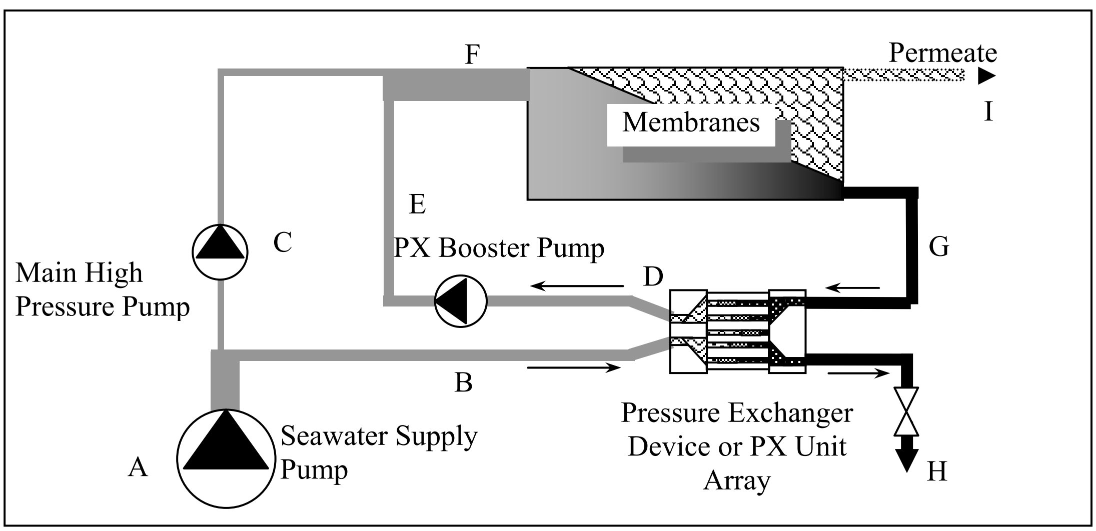
Figure 4-2 illustrates the typical flow path of a PX energy recovery device in an SWRO system. The reject brine from the SWRO membranes (G) passes through the PX unit, where its pressure

Figure 4-1. Flow Path through a PX Unit



is transferred directly to a portion of the incoming raw seawater at up to 97% efficiency. This pressurized seawater stream (D), which is nearly equal in volume and pressure to the reject stream, passes through a booster pump (not the main high-pressure pump) to add the small amount of pressure lost to friction in the PX unit, the membranes and the associated piping. The booster pump also serves to drive the flow of the high-pressure stream through the PX unit (G and D). Fully pressurized seawater then merges with the high-pressure pump discharge to feed the membranes.

Figure 4-2. Typical Flow Path of an SWRO System with a PX Unit



4.2 PX Energy Recovery Devices in SWRO Systems

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

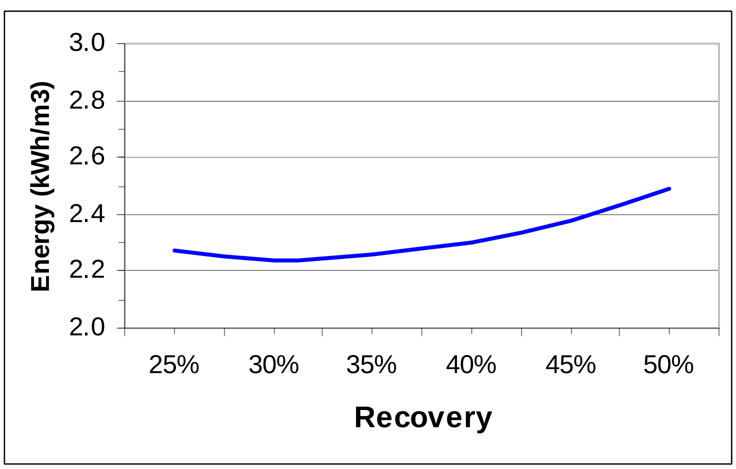
Example flow rates and pressures for an SWRO system with one PX-90S are listed in Table 4-1 below with reference to Figure 4-2. In an SWRO system with an ERI energy recovery device installed, the main high-pressure (HP) pump is sized to equal the SWRO permeate flow plus a small amount of bearing lubrication flow, not the full SWRO 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. In a typical SWRO system with a PX unit operating at 40% recovery, the main HP pump will provide 41% of the energy, the booster will provide 2% and the PX unit will provide the remaining 57%. Since the PX unit uses no external power, a total power savings of 57% is possible compared to a system with no energy recovery.

Table 4-1. Typical SWRO System Flows and Pressures

STREAM	DESCRIPTION	FLOW RATE GPM / M3/HR	PRESSURE. PSI / BAR
A	Seawater Supply	133 / 30.2	25 / 1.7
B	LP IN to PX Unit / Seawater	78 / 17.7	25 / 1.7
C	Main HP Pump outlet	55 / 12.6	1000 / 69
D	HP OUT of PX Unit / Seawater	78 / 17.7	957 / 66
E	Booster Pump Outlet / Seawater	78 / 17.7	1000 / 69
F	SWRO Feed Stream	133 / 30.2	1000 / 69
G	HP IN to PX Unit / Reject	80 / 18.2	971 / 67
H	LP OUT of PX Unit / Reject	80 / 18.2	15 / 1.0
I	SWRO Product Water	53 / 12.1	5 / 0.3

An SWRO system with ERI energy recovery device(s) can operate efficiently at low recovery rates because PX units replace all of the reject-brine flow with a nearly equal volume of feed-seawater at up to 97% efficiency. One advantage of operating at lower recoveries with PX energy recovery devices is that a lower operating pressure is required to produce a given amount of permeate. Since the main high-pressure-pump flow rate always equals the permeate flow rate plus the hydrodynamic bearing lubrication flow rate, low energy consumption at low recovery rates is possible with ERI technology. The overall energy consumption of an SWRO plant using the PX energy recovery device(s) typically has a minimum point at recovery rates of between 30-40%. Outside this recovery range, the plant will start to consume slightly higher amounts of power. Figure 4-3 illustrates the relationship between SWRO recovery rate and overall SWRO power consumption.

Figure 4-3. SWRO Plant Energy Consumption as a Function of Recovery Rate



4.3 PX Energy Recovery Device Performance

PX Pressure Exchanger device performance data for a range of possible flow and pressure conditions is provided on Energy Recovery, Inc.'s website. The following data are given in the form of performance curves:

- High- and low-pressure pressure drop as a function of flow rate
- Minimum discharge pressure as a function of flow rate
- Volumetric mixing as a function of flow rate
- Noise as a function of flow rate
- Lubrication flow as a function of high-pressure pressure

4.4 The PX Booster Pump

In the typical SWRO system illustrated in Figure 4-2, a booster pump is required to add pressure to the seawater from the PX unit before it merges with the high-pressure feed to the membranes. A pressure boost is necessary to compensate for friction losses in the membranes, the PX unit and the associated piping. The flow and pressure supplied by the booster pump must be controlled with a variable frequency drive or control valve because the booster pump controls the high-pressure flow rate through the PX unit. Recommended practice is to use a slightly oversized booster pump to handle projected RO membrane flows taking into account seasonal variations, membrane fouling and manifold losses. Energy Recovery, Inc. carries a line of PX Booster Pumps with capacities up to 300 gpm (68 m^3/hr). ERI PX Booster Pumps can be manifolded to run in parallel to achieve higher capacities. Alternately, several suppliers of high-capacity booster pumps are listed on Energy Recovery, Inc.'s website.

4.5 Control of Feed Flow, Pressure and Permeate Water Quality

The flow rate, pressure and quality of the feed streams to the PX unit(s) must be monitored and controlled. Operation and control of a PX unit in an SWRO system can be understood by considering two parallel pipes, one of high-pressure water and one of low-pressure water flowing through the PX unit. With reference to Figure 4-2, the high-pressure water flows in a circuit through the membranes, the PX unit or PX unit array, the booster pump and back to the membranes (F→G→D→E) at a rate controlled by the booster pump with a variable frequency drive or a throttle valve at the booster pump discharge. The low-pressure water flows from the seawater supply pump through the PX unit or PX unit array to the system discharge (A→B→H) at a rate controlled by the supply pump and a throttle valve in the brine discharge from the PX unit or PX unit array (H). Since the high- and low-pressure flows are independent, the SWRO plant must be designed for monitoring and control of the flow rates of both streams.

Special consideration should be given to flow and pressure control of the seawater 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. 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 LP pressure flow through the PX unit will change accordingly. As long as the maximum allowable feed flow to the PX unit is not exceeded, the PX unit will automatically adjust to small pressure and flow variations. However, 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 SWRO trains as trains go on- and off-line. An automatic flow control system is typically not responsive enough to provide constant flow during sudden pressure changes. Emergency shutdown sequences should include shutting down the seawater supply pump(s) to avoid overflow. Designers of large plants should consider installing a dedicated pump for supplying seawater to the PX unit or PX unit array at a constant controlled flow rate. If large low-pressure spikes and overflow cannot be avoided, a pressure regulator and/or relief valve should be installed before the PX units to help stabilize flow. Where feasible, Energy Recovery, Inc. recommends incorporation of a high flow alarm on the seawater supply set at 95% of PX unit capacity and an automatic high flow shutdown at a maximum of 100% of capacity.

CAUTION

The maximum allowable feed flow rate to the PX unit should never be exceeded. Damage to the PX device may occur.

4.6 Fresh Water Flushing

The SWRO 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 grown 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 shutdowns may result in excessive biological growth that may foul the PX unit and inhibit rotation upon start-up.

4.7 Debris and Initial Flushing

Debris and/or air in the feed streams to the PX unit can damage the device. All piping systems should be flushed prior to initial startup to remove any debris. All air must be purged from both the low- and high-pressure circuits before the system is SWRO pressurized. If the SWRO system is to be started up automatically, sufficient time must be allowed in the startup sequence for air to be purged from the system before starting the HP pump. During 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. Energy Recovery, Inc. recommends installation of basket strainers at both inlets to the PX device or PX device array. Such devices protect the PX unit(s) from damage by debris generated by upstream failures that can occur over time related to corrosion, wearing parts or filter failures. Alternately, Energy Recovery recommends installation of temporary startup strainers during startup and commissioning activities. Energy Recovery can provide a list of strainer vendors upon request.

DANGER

All air and gas in the SWRO system must be purged prior to pressurization. Large bubbles in a pressurized system can result in catastrophic piping and equipment failure.

CAUTION

Thoroughly flush associated piping with water filtered to 5 microns before installing the PX unit. Foreign material may cause damage.

4.8 High Pressure Remains After Shutdown

The high-pressure section of an SWRO system with a PX energy recovery device can remain pressurized for a long time after a shutdown. Pressure decreases as water 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.

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

4.9 Low Pressure Isolation and Over Pressurization

If the low-pressure flow stream 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 over-pressurization, appropriate relief valves and procedures should be implemented to assure that the high-pressure side of the PX unit is depressurized prior to isolation of the low-pressure side.

4.10 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. To assure even flow distribution in a membrane rack or a PX unit array is to eliminate manifold constrictions by using large manifold pipe diameters. 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. 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 low. If one of the PX units is not functioning properly, the salinity of the low-pressure discharge from the unit will be lower than the other units. If a rotor is stuck, the salinity from the stuck unit will be close to the salinity of the seawater feed.

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

CAUTION	When connecting multiple PX units together in parallel, they all must be of the same capacity.

5.0 INSTALLATION

The 4S-series PX energy recovery device can be installed in horizontal, vertical or any other orientation. The PX-45S, -70S and -90S have four connections labeled HP IN, HP OUT, LP IN, and LP OUT. The PX-140S has dual HP OUT and LP IN connections and single HP IN and LP OUT connections.

- **HP IN** is the high-pressure reject/brine inlet.
- **HP OUT** is the high-pressure seawater outlet.
- **LP IN** is the low-pressure seawater inlet.
- **LP OUT** is the low-pressure reject/brine outlet.

The external fittings on the PX energy recovery device are made with AL-6XN®, 254 SMO®, or equivalent stainless steel. The vessel is made of glass-reinforced plastic. Proper piping, piping support, and vessel support must be implemented to minimize external stresses on all piping fittings. Bearing pads should be used to avoid abrasion of the vessel. Flexible couplings should be used for joining fittings and piping. Use only water-soluble lubricants such as glycerin or soap on all O-rings and seals. Do not use grease! Section 13.0 contains an installation diagram/piping detail for use for piping, manifold, and support rack design.

CAUTION	A pressure gauge should be installed near each pipe connection to the PX unit or PX unit array to facilitate monitoring of PX unit performance.
CAUTION	Thoroughly flush associated piping with water filtered to 5 microns before installing the PX unit. Foreign material may cause damage.
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 do not lift the PX by the ports.

6.0 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 assure safe operation and a long service life. Failure to observe these conditions and precautions can result in violation of the warranty, damage to the equipment, and/or harm to personnel. Table 6-1 provides a summary of system performance limits.

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Table 6-1. System Performance Limits

Parameter	Specification	
	English Units	SI Units
Maximum high pressure (HP IN or HP OUT)	1,200 psig	82.7 bar
Maximum feedwater inlet pressure (LP IN)	300 psig	20.7 bar
Minimum feedwater inlet pressure (LP IN)	27 psig	1.9 bar
Minimum brine discharge pressure (LP OUT)	15 psig (1)	1.0 bar
Minimum filtration requirement (nominal)	5 micron	
Seawater temperature range	33-120 ºF	1-49 ºC
pH range	1-12 (short term at limits)	
Allowable flow rates (2)		
PX-45S	25-45 gpm	5.7-10.2 m^3/hr
PX-70S	40-70 gpm	9.1-15.9 m^3/hr
PX-90S	60-90 gpm	13.6-20.4 m^3/hr
PX-140S	90-140 gpm	20.4-31.8 m^3/hr

(1) The low pressure discharge stream from the PX unit must be constricted to provide backpressure. Without backpressure, the noise profile will increase and destructive cavitation may occur resulting in damage to the device(s).

(2) Unlimited system capacities are achieved by using multiple units in parallel.

DANGER

Do not allow the high-pressure reject feed to the PX unit to exceed 1,200 psi (83 bar). If necessary, install a pressure switch and/or safety valve in the high-pressure line(s) to ensure the system does not exceed 1,200 psi (83 bar).

DANGER

The lock ring segments in 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.

CAUTION

Do not allow the high-pressure or low-pressure stream flow rates to exceed the flow rates listed in Table 6-1. It is necessary to install flow meters on both the high-pressure stream and on the low-pressure steam to comply with the warranty. Failure to do so can result in damage or destruction to the PX unit and/or other equipment.

CAUTION

When connecting multiple PX units together in parallel, they all must be of the same capacity.

CAUTION

Introduction of non-water soluble films such as grease, oil, wax, petroleum jelly, etc. may cause the PX unit’s rotor to seize.

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.
- Seawater feed to PX units must be filtered to 5 microns or less and should be subjected to the same pretreatment as seawater being fed to the SWRO membranes.
- Entrained or trapped air or other gasses must be purged from the SWRO 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 vessel.
- The PX unit vessel-bearing plates (end caps) incorporate interlocking restraining devices. 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 and corrosion.
- The PX unit must never be exposed to temperatures less than 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 1,200 psig (82.7 bar).
- The seawater feed inlet pressure shall not exceed 300 psig (20.7 bar). The minimum discharge pressure from the PX unit shall be 15 psig (1.0 bar).
- The PX unit(s) must be removed from the SWRO system when performing hydrostatic testing on piping or other SWRO 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. Always ensure the operating limits listed in section 6.1 are not exceeded.

6.2.1 System Start Up Sequence

1. All valves should be in their normal operating positions.
2. Start the seawater 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 seawater flow to the desired flow rate.
4. Bleed air from the system.
5. After the PX device has run with seawater for 5 to 10 minutes, start the PX booster (brine) pump. Rotor speed will increase and remaining air will be released from the PX unit. Bleed any remaining air from the system.

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 5 to 10 minutes and all air and gas has been purged from the system, start the main high-pressure pump. The SWRO 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 the high- and low-pressure flow rates. Adjust flows as necessary to achieve balanced flow to the PX unit.
9. Verify that brine reject pressure (LP OUT) is above minimum requirements.

6.2.2 Short Term (1-3 Days) System Shut Down Sequence

1. Stop the main high-pressure pump.
2. Wait until the system pressure drops below 400 psig (28 bar). Open a purge valve if necessary to expedite depressurization.
3. Stop the PX booster pump.
4. Stop the seawater inlet supply pump.

6.2.3 Medium Term (4-14 Days) System Shut Down Sequence

1. Feed the PX unit and SWRO system with fresh water. A feed pressure of 27 psi (1.9 bar) is necessary to assure complete flushing.
2. Make sure booster pump is operating. Run the system for 5 to 10 minutes until all the seawater is purged.
3. Stop the booster pump.
5. Isolate the fresh water supply source.

NOTE	The main high-pressure pump should never be operated without the booster pump. An interlock should be installed so that the high-pressure pump will automatically shut down if the booster pump shuts down.
NOTE	Continuous operation of the main high-pressure pump is not recommended during the fresh water flush sequence, however momentary operation of the pump will help purge seawater from the PX unit and membranes.
NOTE	A minimum of 27 psi (1.9 bar) is required to feed the PX unit low-pressure inlet. The fresh water flush will not occur without sufficient pressure.

6.2.4 Long Term (Over 2 Weeks) System Shut Down Sequence

If a plant is to be shut down for an extended period of time, the SWRO 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 flush should flushed with fresh water through the seawater 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 SWRO membranes.

CAUTION

The PX unit must be flushed with fresh water for extended shutdowns to avoid excessive biological growth 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.

6.2.5 Membrane Cleaning

PX unit(s) must be isolated from the reverse osmosis system whenever a chemical cleaning of the membranes is being performed to prevent debris from the membrane from entering the PX device. If isolation valves are not provided in the system design, the PX units must be removed during such cleanings.

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 Balancing the System

Flow rates and pressures in a typical SWRO 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.

The following subsections make references to PX unit installation process and instrument diagrams provided in Section 13.0.

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. The flow rate of the high-pressure seawater 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.

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.

NOTE

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

6.3.2 Low Pressure Flow Control

The low-pressure flow through the PX unit is controlled by the seawater 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 seawater to the PX unit plus the bearing lubrication flow rate.

Caution should be exercised when considering installing a flow meter on the low-pressure discharge of the PX unit as low-pressure brine is often foamy.

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 in the 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 flows should be set equal to within 5.0% for optimum SWRO operation. Similarly, the high- and low-pressure seawater flows should be set equal to within 5.0%. If any doubt exists in reading the flow meter, see Section 6.3.4 below.

Operating the PX unit with unbalanced flows can result in contamination of the seawater feed by the brine reject. The PX device is designed to operate at fluid mixing levels at or below 6 percent. Balanced flows help limit mixing of concentrate with the feed. Flowing the seawater inlet much less than the seawater 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 seawater from the PX unit.
2. Adjust the seawater supply rate or the throttle valve on the low-pressure reject from the PX unit until the low-pressure seawater inlet flow rate equals the high-pressure seawater 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.

6.3.4 Verification of PX Energy Recovery Device Flow Balance

Once the PX energy recovery device has been balanced using flow readings, balance can be verified by checking the salinity of the high-pressure seawater from the PX unit. If the high- and low-pressure flows through PX unit are balanced, the conductivity at the PX unit high-pressure outlet should be 3-4% higher than the conductivity of the low-pressure seawater supply. Concurrently, the conductivity of the PX unit low-pressure outlet should be 3-4% lower than the conductivity of the high-pressure brine. If the conductivity of the PX unit high-pressure outlet is too high, the high-pressure flow rate is probably higher than the low-pressure flow rate causing “blow through” of brine inside the PX unit. High salinity from the PX unit increases osmotic pressure in the membranes which may reduce membrane productivity. See the Trouble Shooting Guidelines in Section 9.0 for more information.

Low conductivity in the PX unit low-pressure outlet is an indication of low-pressure overflow. Although membrane productivity is not typically compromised by excess low-pressure flow, the excess flow goes to the brine discharge and represents a loss of plant pretreatment costs and capacity. Caution should be exercised to prevent overflow of the PX unit by high low-pressure flow.

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 Energy Recovery, Inc.'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 seawater to the main 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 seawater 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 seawater to the PX unit. The difference is the lubrication flow rate.

Although each of these methods should provide the same result, Energy Recovery, Inc. recommends measuring lubrication flow using the first method because the flow meters necessary to collect flow data according to this method are typically already incorporated into the SWRO plant design.

7.0 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, Energy Recovery, Inc. recommends use of the following:

ALL 4S-Series PXs:	4S Tool Kit – Energy Recovery, Inc. Part Number 20023-01
PX-45S, -70S, -90S:	4S Single Rotor Spares Kit – Energy Recovery, Inc. Part Number 20018-01
PX-140S:	4S Dual Rotor Spares Kit – Energy Recovery, Inc. Part Number 20019-01

Replacements for other components in the PX unit assembly are available. Refer to Section 13.0 for PX device component names and the bill of materials for the PX unit assembly.

8.0 MAINTENANCE

If the inlet and outlet flows are measured and balanced properly, the seawater is filtered and the PX unit is properly flushed after every shut down (as described in Section 6.2), the PX device should operate maintenance- and trouble-free for many years. The PX unit needs no scheduled periodic maintenance. There are no shafts, couplings, seals or lubrication systems to maintain or monitor.

NOTE

A sample operating-log has been provided at the end of Section 8.0 and must be submitted by fax or e-mail to Energy Recovery, Inc. in San Leandro, California upon completion of the startup and balancing routines. Submittal of this form with the initial startup data within 24 hours of startup is requested. The data must be recorded daily and maintained during the life of the warranty to support any claims.

The PX unit is designed so that it can be assembled and disassembled in the field with basic tools and equipment. 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 13.0 for PX device component names and the bill of materials for the PX unit assembly. Refer to Section 7.0 for recommended spare parts and tool kits. If the PX unit must be assembled or disassembled, the tools and fixtures listed in Table 8.1 are required.

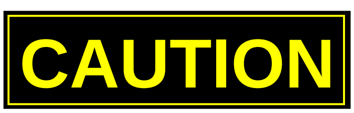
Table 8.1 - Tools Required for Assembly and Disassembly

EQUIPMENT	PURPOSE
lifting eye bolt (supplied with PX unit)	for extracting ceramic cartridge from vessel
3/16 – inch Allen wrench	for removing hex screws from lock rings
2 1 /2 – inch box wrenches	to assemble and disassemble the ceramic cartridge
inside wrench or strap wrench	for removing ports
torque wrench	to assemble the ceramic rotor subassembly
slide hammer OR claw hammer/crow bar	for removing access covers
water-soluble lubricant (e.g.: glycerin)	for installing O-rings

8.1 Disassembly Procedure

The procedure provided in this subsection is for complete disassembly of a 4S Series PX energy recovery device. Refer to Section 7.0 for a listing of spare parts kits and tool kits useful for disassembly and reassembly of a PX unit. For single rotor models (PX-45S, PX-70S or PX-90S), the internal components are reached through the seawater end of the vessel, therefore only the seawater access cover needs to be removed. For the PX-140S, the internal components are reached through both ends of the vessel. Refer to Section 13.0 for PX device component names and bills of materials for PX unit assemblies.

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



When handling and installing a PX unit, do not drop the unit or put undue strain on the port fittings to avoid internal damage.

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. Disconnect all flexible couplings from the high- and low-pressure ports. Drain the PX unit. Place the PX unit on a sturdy table for service.
3. Remove low pressure LP inlet port (LP IN) from the end of the PX unit using an inside wrench or a strap wrench. See Figure 8.1.

Figure 8.1 - Remove LP IN port from the end of unit

4. Remove the six (6) socket head cap screws from the access cover(s).
5. Remove fiberglass locking ring segments. It may be necessary to tap down on the access cover to relieve compression between the access cover and locking rings. See Figure 8.2 below.

Figure 8.2 – Remove cap screws, locking rings and access cover from the end of unit. Tap down to loosen access cover if necessary.

6. Remove access cover by one of the following methods:
   a. If using Energy Recovery, Inc. 4S Series Tool Kit, bolt the slide hammer onto the access cover. Pull access cover.
   b. If slide hammer is not available, reinstall LP port into access cover with flexible coupling as shown in Figure 8.3. Pry off the access covers with a claw hammer or a crow bar. Use a section of the segmented locking ring to protect the vessel housing from damage while prying.

Figure 8.3 – Pry off access cover using LP port with flexible coupling

CAUTION

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

7. Remove the low-pressure nipple.
8. Mark the vessel to facilitate correct alignment of the cartridge during reassembly. See Figure 8.4.
9. Thread the lifting eye bolt (5/16”-18) into the standoff on the ceramic cartridge. Extract the ceramic cartridge. See Figure 8.5. For Single Rotor 4S Series PXs (PX-45S, PX-70S or PX-90S), the ceramic cartridge must be removed from the seawater (LP IN / HP OUT) end.
10. Stand the ceramic cartridge on blocks allowing clearance for the tension bolt, nuts, and stand-offs on the bottom of the cartridge. See Figure 8.6 which illustrates the correct orientation of the cartridge.

Figure 8.4 – Mark vessel to recall alignment

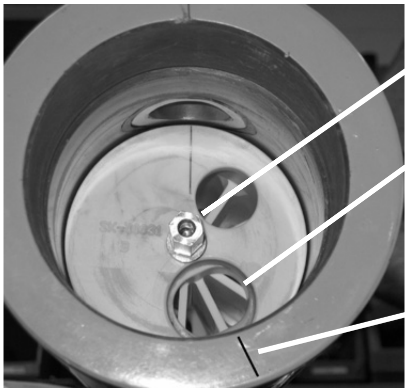
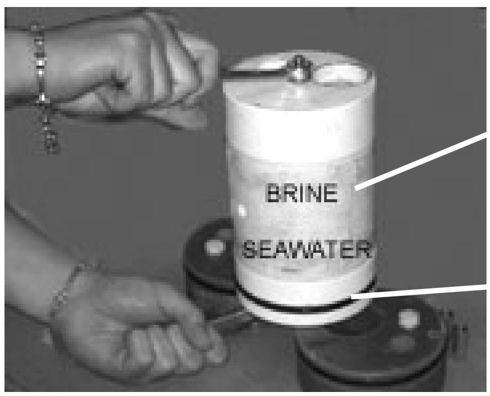


Figure 8.5 – Thread lifting eye into standoff

Figure 8.6 – Stand ceramic cartridge on blocks



11. Mark the ceramic sleeve with a pencil or marker to assure that correct orientation is retained as shown in Figure 8.6. The ceramic components must be returned to the vessel in the same orientation they were removed. Use a pencil or marker to write “SEAWATER” or “BRINE” on the sleeve to assist with reassembly. The seawater endcover has an O-ring on the outside.
12. Remove the stand-offs from the both ends of the tension rod assembly.
13. Remove the nuts and washers from both ends of the tension rod assembly.
14. Lift the ceramic endcover off the rotor and sleeve. Set the endcover on a clean surface with the polished side oriented upwards.
15. Lift the rotor and sleeve off the bottom endcover. DO NOT ALLOW THE ROTOR TO COME OUT OF THE SLEEVE. Place the rotor and sleeve on a clean surface. 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. Rinse again 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”. If the sleeve is marked “CHK”, orient the end marked “CHK” upward. If the sleeve is marked “CHK SWP”, orient the end marked “CHK SWP” downward.
    e. 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 Energy Recovery, Inc. immediately if ceramic is damaged or broken or if problems are encountered. Do not attempt to reassemble a PX unit with damaged or broken parts.

16. Remove the low pressure nipples.
17. The PX-140S contains a center manifold which is not normally removed. However, the center manifold can be removed by removing both side ports using an inside wrench as shown in Figure 8.7. After removal of the ports, the center manifold will easily slide out of the vessel.

Figure 8.7 – Remove PX-140S side ports with inside wrench if removing center manifold

CAUTION

Use extreme caution when handling ceramic components. Do not attempt to reassemble a PX unit with contaminated, damaged or broken parts. Permanent damage may result.

8.2 Assembly Procedure

This assembly procedure assumes that the PX energy recovery device has been disassembled per the previous section. All parts should be carefully cleaned with soap and water prior to assembly to assure that no dirt or debris contaminates the PX unit. All parts should be thoroughly inspected for damage and/or debris prior to reassembly. O-rings should be carefully inspected for damage and should be replaced if damage is apparent. Do not attempt to reassemble a PX unit with damaged or broken parts. Refer to Section 7.0 for a listing of spare parts kits and tool kits useful for disassembly and reassembly of a PX unit. Refer to Section 13.0 for a complete listing of PX device component names and the bill of materials for PX unit assembly.

CAUTION

Do not attempt to reassemble a PX unit with contaminated, damaged or broken parts. Permanent damage may result.

1. Insert dowel pins into the 3 holes in the face of one endcover as shown in Figure 8.8. 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.

CAUTION

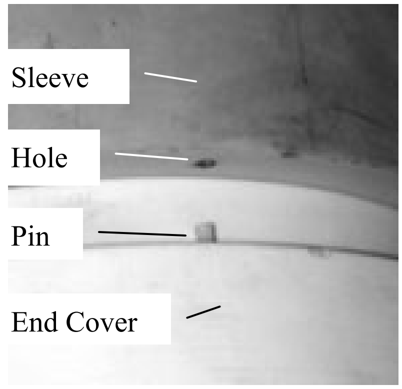
Alignment pins must not bind or be shaved during installation. Carefully inspect ceramic contact lines after installation for any indication of pin damage or binding.

2. Place the rotor and sleeve on the endcover. Make sure that the dowel pins in the endcover line up with the 3 holes in the sleeve as illustrated in Figure 8.9.

3. Insert dowel pins into the 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.

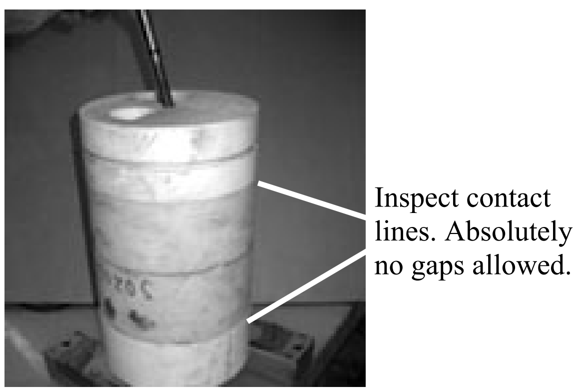
Figure 8.8 – Insert 3 pins

Figure 8.9 – Align pins with holes in sleeve



4. Stack the ceramic as shown in Figure 8.10. The end of the rotor/sleeve assembly, which was marked “SEAWATER” during disassembly, must be oriented toward the seawater endcover. The seawater endcover has an O-ring on it.

Figure 8.10 – Complete ceramic stack



5. 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. Repeat assembly.

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.

6. 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!

CAUTION

Introduction of non-water soluble films such as grease, oil, wax, petroleum jelly, etc. may cause the PX rotor to seize.

7. Insert the tension rod through the ceramic endcovers and rotor as shown in Figure 8.10 above.

8. Center the rod on the assembly.
9. Install the washers and hex nuts as shown in Figure 8.11.
10. Install the hex nuts. Tighten and torque the hex nuts onto ceramic rotor subassembly to 10 ft-lb (14 N-m) as shown in Figure 8.12.

Figure 8.11 – Tension rod washers and nuts

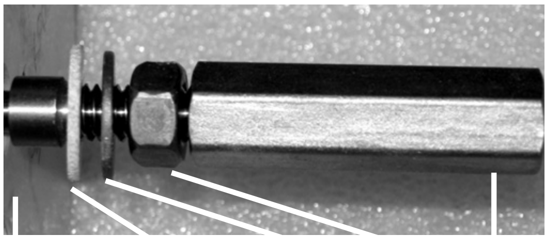
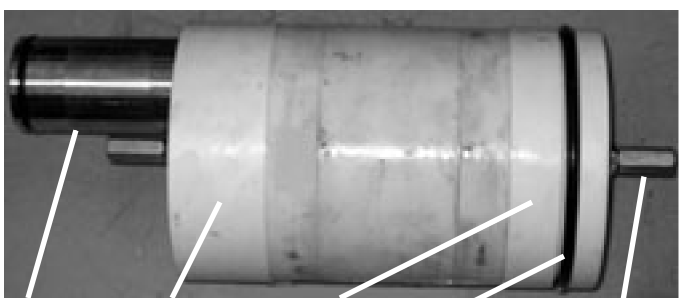


Figure 8.12 – Torque inside nuts to 10 ft-lbs (14 N-m)

11. Thread the standoffs onto the tension rod. Torque each standoff to 14 ft-lb (20 N-m) against the nut.
12. Lubricate the O-rings of one low-pressure nipple with a water-soluble lubricant. Insert the LP nipple into the countersink of the brine endcover. The brine endcover does not have an O-ring groove.
13. Lubricate the O-ring on the seawater endcover. The completed ceramic cartridge assembly, shown in Figure 8.13, is now ready to go into the vessel.

Figure 8.13 – Complete ceramic cartridge



14. If reassembling a PX-140S and the center manifold was removed during disassembly, the following procedure should be used for re-installing the center manifold:
    a. Correctly orient the center manifold as shown in Figure 8.14.
    b. Insert the center manifold into the vessel.
    c. Inspect the O-rings on the side ports for any damage (2 per side port). Lubricate the O-rings.
    d. Insert the side ports into the vessel and thread into the center manifold. See Figure 8.15.

Figure 8.14 – Orient center manifold with vessel

Figure 8.15 – Screw side ports into center manifold

15. Generously lubricate the inside of the vessel with glycerin.
16. Insert the ceramic cartridge into the vessel as shown in Figure 8.16. Make sure that the brine LP nipple (shown in Figure 8.13) is aligned with the countersink in the vessel. For a PX-45S, -70S or 90S, the LP nipple must be aligned with the countersink in the brine access cover. For a PX-140S, the LP nipple must be aligned with the countersink in the center manifold. See Figure 8.16. To assist with alignment, the seawater endcover has a tick mark that should be centered on the HP OUT port opening. See Figure 8.18. Precise alignment of the tick mark with the port will help assure that the brine LP nipple (not visible) is correctly aligned with the countersink inside the vessel.

Figure 8.16 – Insert ceramic cartridge

Figure 8.17 – PX-140S top view

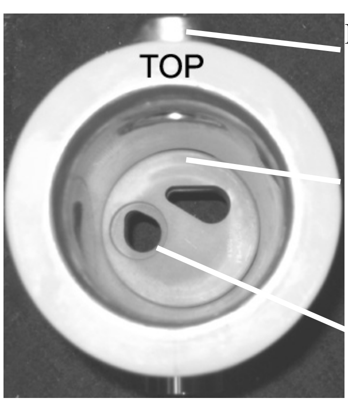
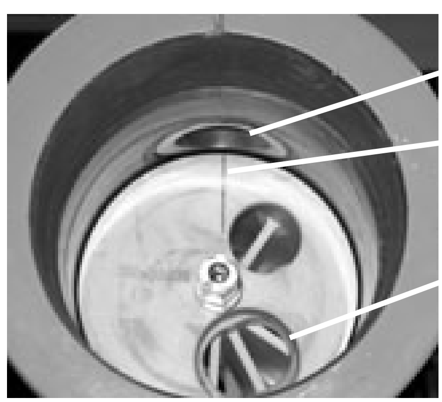
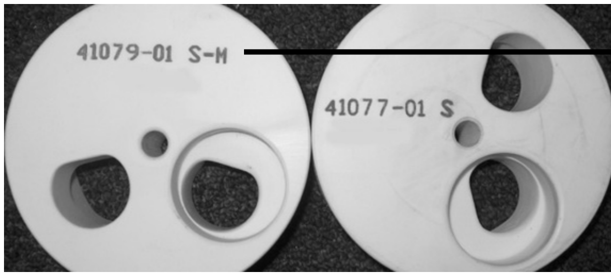


Figure 8.18– Align tick mark on endcover with port



17. NOTE: The top and bottom ceramic cartridges in a PX-140S differ. The bottom cartridge is a mirrored version of the top cartridge. Therefore, the top cartridge must be returned to the top of the vessel and the bottom cartridge to the bottom of the vessel. The mirrored endcovers are marked with an "-M" to assist with distinguishing between the two types of cartridges. See Figure 8.19.

Figure 8.19 – PX-140S standard and mirrored endcovers



"-M" designation indicates mirrored endcover

18. When the ceramic cartridge is correctly aligned with the port as shown in Figure 8.18, push the cartridge into the vessel to seat the brine LP nipple. A slight bump will be felt as the nipple seats in the countersink.

CAUTION

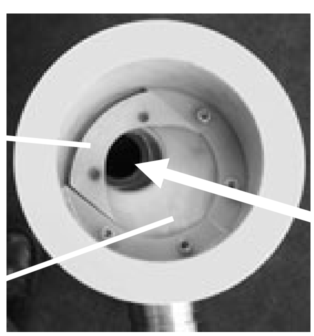
Use extreme caution when handling ceramic components. Do not attempt to reassemble a PX unit with contaminated, damaged or broken parts. Permanent damage may result.

19. Remove the lifting eye from the standoff.
20. Lubricate the O-rings of another low-pressure nipple with a water-soluble lubricant. Insert the LP nipple into the countersink of the endcover in the vessel. See Figure 8.18.
21. Mount the quad ring onto the fiberglass access cover. Lubricate the quad ring.
22. Insert the access cover into the vessel. Make sure the low-pressure port lines up with the low-pressure nipple. This can be verified by looking into the access cover while inserting it into the vessel. See Figure 8.20 below. If the access cover does not insert fully, the low-pressure nipple may not be correctly aligned with the access cover or the countersink in the ceramic endcover. If the low-pressure port, LP nipple and endcover are not aligned, remove the access cover, check for chipped or pinched O-rings, and try again.
23. Insert the 3-part segmented lock ring into the space between the access cover and the vessel. Refer to Figure 8.20. If the segments will not fit, this is an indication that one or more low-pressure nipple is not correctly aligned with an access cover. Verify alignment of the LP nipple and the access cover as described in the previous step. If the access cover still does not insert fully, this is an indication that the LP nipple on the brine endcover is not correctly aligned with the brine access cover or center manifold. Remove the access cover, align the ceramic cartridge as described above, and try again.

Figure 8.20 – Install access cover, lock ring and hex screws

Segmented locking ring

Access cover



Look into access cover to verify alignment of LP nipple

24. Bolt down the lock ring with six (6) socket-head cap screws.
25. Inspect and lubricate the O-ring on the LP port. Install the LP port into the access cover.

CAUTION	When handling and installing a PX device, 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.

ENERGY RECOVERY, INC. SAMPLE OPERATING LOG

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

Fax: +1 510 483 7371 Attn: Warranty Administration Department

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

9.0 TROUBLE SHOOTING

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 guidance. The best troubleshooting tool is the knowledge, experience and day-to-day observations compiled by the SWRO plant operator. Conditions not covered in this section may be resolved by contacting Energy Recovery, Inc.'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.

When using this troubleshooting guide, please read all the probable causes before taking any action. Use good common sense and the probable cause that most likely fits the given situation.

Table 9-1. Troubleshooting

SYMPTOM	PROBABLE CAUSE	CORRECTIVE ACTION
A. Excessive noise 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 booster 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 valve (V8). 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 brine inlet. If service was performed, verify the orientation of the ceramic cartridge by removing the brine-side port bearing plate assembly. The endcover marked "B" should be oriented toward the brine inlet/outlet.
	5. Damaged ceramic.	Contact the Energy Recovery, Inc. Service Department.

B. Excessive high pressure in SWRO system.	1. Main 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 SWRO system.	Reduce recovery by increasing and balancing flows through the PX unit(s). Do not exceed recommended maximum 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 SWRO feed water salinity.	See Section 6.3.
	4. Stuck rotor.	See Symptom D.
C. High salinity in high-pressure seawater 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 reject water with high-pressure feed water. No exchange occurs; no audible rotation.	See Symptom D.
	3. Malfunctioning and/or stalled booster pump.	Check booster pump's rotation, operation, flows, and pressures.
D. Stalled rotor - no audible rotation.	1. Operating system above rated pressure or below rated flow capacity.	Check pressures and flows. See Table 6-1
	2. Foreign debris or particles lodged in device.	Contact the Energy Recovery, Inc. Service Department.
E. Low permeate flow.	1. Malfunctioning high-pressure pump.	Verify high-pressure pump flow rate and pressure.
	2. High lubrication/leakage flow through PX unit(s).	Leaking seal inside PX unit or stalled rotor. Confirm that all rotors are rotating. If not, see Symptom D. If all rotors are rotating, contact the Energy Recovery, Inc. Service Department.

F. Low reject flow.	1. Excessive pressure losses through SWRO system. 2. Malfunctioning and/or stalled booster pump.	Contact SWRO supplier. Check booster pump operation, flows, and pressures.

10.0 FIELD COMMISSIONING

The Technical Services staff of Energy Recovery, Inc. offers commissioning service for all ERI products during field installation and/or at a SWRO system manufacturer's location. Although commissioning is not a requirement, some customers might feel more comfortable with the offered service. Rates can be quoted upon request.

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

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11.0 REVISION LOG

Revision Log

Revision	Description	Date	Approval
0	Initial release	7/12/04	R.Stover
1	Revised trademarkings	8/5/04	R.Stover
2	Removed strainers, updated warranty	6/8/05	R.Stover
3	Revised warranty	8/11/05	R.Stover
4	Update installation guidelines	7/17/06	R.Stover

12.0 LIMITED PRIMARY PRODUCT WARRANTY

Energy Recovery, Inc. (ERI) warrants that its Pressure Exchanger (PX) device(s) will not fail or malfunction as a result of defects in materials, workmanship, or design for a period of twenty-four (24) months from date of shipment.

Application

This Warranty (i) extends to the original purchaser only, (ii) shall apply only if the process and instrument diagram, manifold design and operating conditions of the desalination plant are reviewed and approved by ERI (iii) covers a PX unit that is installed and put to use under the intended conditions (unless written approval for alternate conditions is obtained from ERI), and (iv) shall apply only if ERI's written Installation, Operation, and Maintenance instructions and Buyer's Responsibilities have been complied with in full throughout the warranty period. This Warranty shall not apply to damage or wear to a PX unit caused by unprotected storage, abnormal operating conditions, or to accidents, abuse, misuse, or improper disassembly, alterations, or repair.

Limitations

This Warranty is sole and exclusive and in lieu of any rights or remedies otherwise available at law or in equity. In no event shall ERI be responsible or held liable for any indirect, special incidental, or consequential type damages including, by way of example but not by way of limitation, loss of profit, loss of use, loss of product or feedstock, business interruption, or damage caused by the installation or use of ERI's products, however caused, including the fault or negligence of ERI. ERI's aggregate liability shall not exceed an amount equal to the Purchase Price.

Remedy

If a PX unit covered under this Warranty becomes inoperative, ERI will, at its option, either promptly repair or replace the faulty unit. Repair or replacement parts will be supplied Ex-works, San Leandro, California without charge to Buyer except that Buyer shall be responsible for applicable taxes, duties, and installation costs. ERI shall evaluate and repair or replace the inoperative PX unit according to the terms of its Return Material Agreement.

Buyer's Responsibilities

The Buyer shall comply with ERI's written Installation, Operation, and Maintenance Manuals and ERI's other manuals, instructions, and recommendations. In addition, Buyer shall be responsible for performance or forbearance as follows:

1. Buyer shall maintain complete and accurate operating records for the PX unit. These records must show that the PX unit is operated consistently within the operating limits listed in ERI's Installation, Operation, and Maintenance Manuals as updated from time to time on ERI's website: http://www.energy-recovery.com. Buyer will record all of the operating parameters required by ERI at least once per day. Buyer shall make available to ERI all PX unit and plant operating records at any time during normal working hours.
2. The absolute maximum flow through the PX unit, either on the high-pressure (HP) side or the low–pressure (LP) side, must not exceed the rated capacity of the PX unit. Correctly installed and maintained HP and LP flow meters shall be used.
3. The maximum HP service pressure and the minimum LP discharge pressure must be maintained within the ratings of the PX unit. Correctly installed and maintained HP and LP pressure meters shall be used.
4. All piping shall be cleaned and flushed with water so that all debris is removed from the system before installing or operating the PX unit.

5. Entrained or trapped air or other gasses must be purged from the SWRO system before pressurization. Large bubbles in a pressurized system can result in damage to piping and equipment including the PX unit.
6. Feedwater flowing to the PX unit must be treated with nominal 10 micron cartridge filters.
7. The PX unit must be isolated from the RO system when the membranes are being cleaned. If isolation valves are not provided in the system design, the PX unit must be removed during cleaning.
8. Chemicals that are not acceptable to the SWRO membrane manufacturers for application to the membranes used at the plant are not acceptable to ERI. Chemical application levels and frequencies must follow membrane manufacturer's guidelines. Buyer will make a list of chemicals and their application criteria (doses, residence times, etc.) available to ERI. In the unlikely event that it does occur, Buyer is solely responsible for cleaning up any fouling of PX equipment which may result from the dosing of any chemicals. Accordingly, warranty Limitations apply.
9. In preparation for extended plant shutdowns, PX units must be flushed with permeate and a biocide as instructed in ERI's written Installation, Operation and Maintenance instructions.
10. Flushing flow rates must not exceed the maximum allowable flow rate per PX unit.

13.0 DRAWINGS AND DATA

1. PRESSURE EXCHANGER ASSEMBLY DRAWINGS
2. PROCESS AND INSTRUMENT DIAGRAMS