



Making Desalination Affordable

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ERI QUICK START GUIDE FOR NEW PX TECHNOLOGY USERS

Congratulations! You are planning to join the many OEMs, engineering firms and end users who are already saving money by using the Energy Recovery, Inc. “PX” Pressure Exchanger energy recovery device. This guide contains information that will get you started on the right foot. Please understand that it is essential for you to read and comprehend the product manuals, warranty and the technical papers available on the Energy Recovery website that explain in greater detail how a PX system works.

The information contained in this guide is intended to improve your familiarity with PX technology. It is not intended as a replacement or alternative to ERI’s Installation, Operation and Maintenance manuals, product warranties or other technical publications (“ERI’s technical publications”). System operators and designers are required to read ERI’s technical publications in detail prior to installing or starting up ERI equipment. Energy Recovery, Inc. will not be liable for any project delay, damage or injury caused by the failure to comply with the procedures listed in ERI’s technical publications. These documents may be found on ERI’s website: www.energy-recovery.com.

Where do you start?

The Energy Recovery, Inc. sales staff is ready and willing to assist in determining the optimum size and number of PX units and booster pumps needed for your application. You may be planning to add PX units to an existing system or to start from scratch designing a new system that will use PX technology. In all cases, the following information should be provided to ERI sales staff for use in developing a system projection and a quote.

- 1) Permeate production rate
- 2) Recovery rate
- 3) Membrane feed pressure
- 4) Membrane array pressure drop

Things that help to make a proposal more complete but are not 100% necessary are:

- 5) High pressure pump and motor efficiencies
- 6) Local cost of electricity

If your desire is to add PX units to an existing system, and depending on the nature of the retrofit and what you are trying to accomplish (energy reduction, expansion and reduction,

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cheap expansion, maximum expansion), more information about your existing plant may be required.

The PX Pressure Exchanger – What is it? How is it Constructed? How does it work?

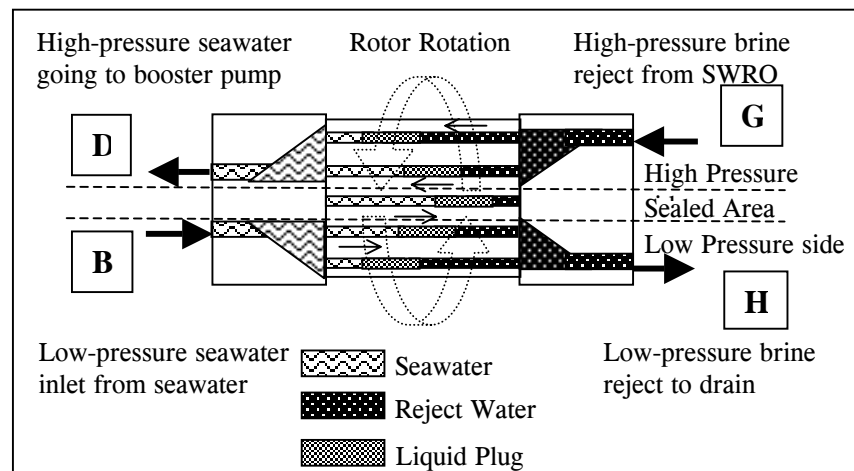
The PX is a positive displacement device that facilitates the transfer of energy (pressure) from one flowing stream to another by putting the streams in direct, momentary contact. PX devices come in a variety of sizes and configurations, but they all consist of a ceramic assembly where the energy transfer takes place inside a fiberglass pressure vessel with grooved, flexible coupling port connections.

The ceramic assembly consists of four primary parts – a rotor with twelve separate chambers or ducts installed inside a sleeve packaged between two end covers. When assembled, the rotor turns inside of the sleeve and between the two end covers. Accurate machining of the ceramic components creates seals that separate high pressure from low pressure. When pressurized and filled with water, the rotor floats on an almost frictionless hydrodynamic bearing. The actual exchange of pressure - from the high-pressure stream to the low-pressure stream - takes place within the rotor ducts. The end covers direct the two streams in and out of the rotor/sleeve assembly and provide the sealing surfaces.

When operating, a high-pressure flow stream and a low-pressure flow stream are directed into the ceramic assembly through the ports. The flow causes the rotor to spin at a speed determined by the flow rate. At any given instant, half of the ducts are exposed to the high-pressure stream and half are exposed to the low-pressure stream. As the rotor turns, the ducts pass a sealing area that separates the high pressure from the low pressure.

A schematic representation of the ceramic components of the PX device is provided in Figure 1. Low-pressure feedwater from the supply pump flows into the PX and is directed by the endcover into a duct on the left side at low pressure (B). This flow expels reject brine through the endcover on the right side (H). After the rotor duct filled with seawater moves past a sealing area, high-pressure brine flows into the right side of the rotor duct, pressurizing the seawater (G).

Figure 4-1. Flow Path through a PX

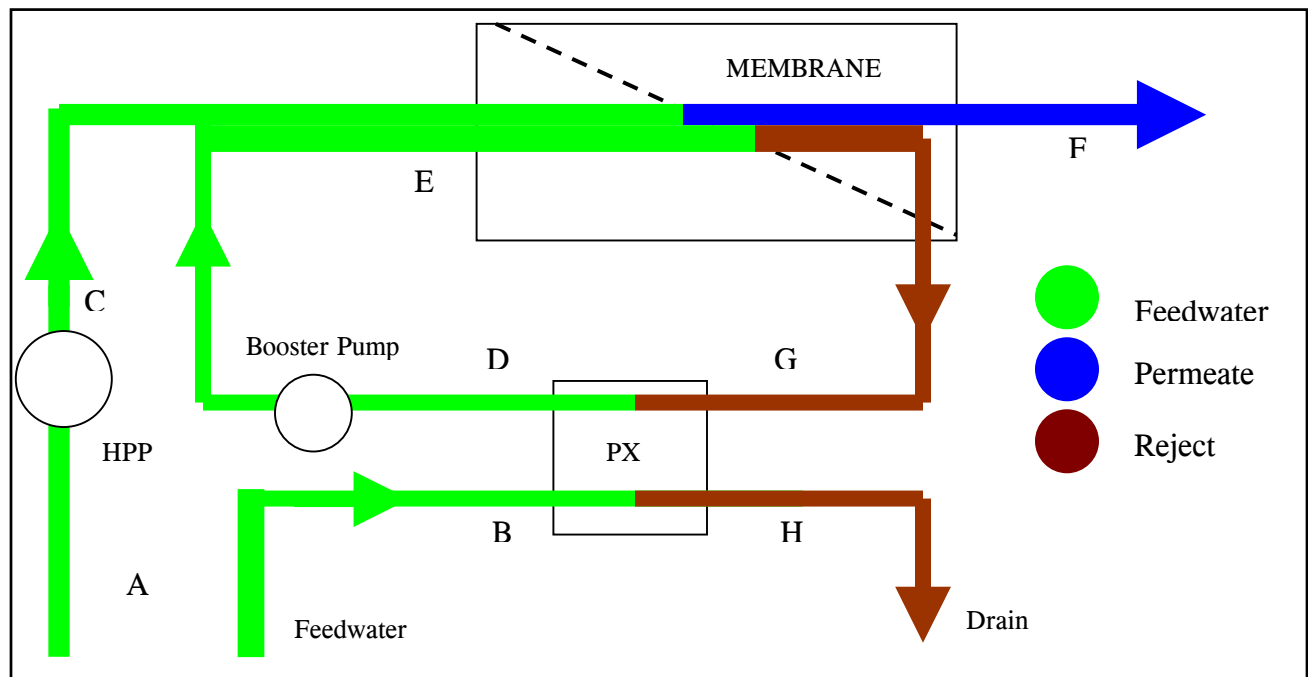


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Pressurized seawater then flows out through the left endcover to the PX Booster Pump (D). This pressure exchange process is repeated for each duct with every rotation of the rotor such that the ducts are continuously filling and discharging. At 1200 rpm, one revolution is completed every 1/20 seconds.

Figure 2 illustrates the flows within a typical SWRO system equipped with a PX unit. Filtered seawater is pumped to both the main high-pressure pump (HPP) and to the low-pressure inlet of the PX unit(s) (B). The pressurized reject brine from the SWRO membranes (G) enters the PX unit and pressurized seawater leaves the PX unit to the booster pump. The booster pump adds the small amount of pressure lost to friction in the PX unit, the membranes and the associated piping. Fully pressurized seawater from the booster pump merges with the seawater from the HPP (C). The combined seawater flow is directed to membrane array. Most of the seawater pumped by the HPP (C) becomes permeate (F). A small percentage of the seawater pumped by the HPP goes to lubricate the PX unit's ceramic cartridge and flows to waste at (H).

Figure 2 – SWRO System with PX Device(s)



The water going to the drain (H) is the depressurized concentrate, but the HP concentrate flow rate to the PX cannot be determined by measuring the flow rate to the drain at (H). If you put a flowmeter at H, the flow rate you will measure will be equal to the PX unit LP inlet flow rate (B) plus the lubricant flow rate. If, for some reason, the PX unit stopped rotating, the feedwater entering the PX unit at (B) would pass straight through the PX unit and exit the system to drain at (H). Simultaneously, the concentrate entering the PX unit at (G) would go straight through the PX unit and would be re-pressurized by the booster pump before flowing to the membrane array. The brine from the PX unit would cause the membrane feedwater salinity to increase and the membrane feed pressure to rise resulting in a system shutdown because of either high operating pressure or high permeate conductivity.

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PX System Terminology

ERI uses specific terminology when discussing how to design and operate PX energy recovery devices with customers. The following definitions make reference to Figures 1 and 2.

Low Pressure Flow - The low-pressure flow path brings feedwater to the PX unit and carries the spent brine concentrate to drain. There are connection points on the PX unit labeled “LP IN” (low pressure flow into the PX unit) and “LP OUT” (low pressure flow out of the PX unit). LP IN is labeled “B” on Figure 1. LP OUT is labeled “H” on Figure 1. Flow from the feedwater source, into the PX unit at “B” and out of the PX unit at “H” to the drain is the low-pressure flow path. There is a required minimum backpressure on the PX unit – the pressure sensed at “H” – of 15 psi or 1 bar. Usually, the pressure at “B” will be 30 to 60 psi or 2 to 4 bar.

High Pressure Flow – The high-pressure flow circuit brings concentrate from the reject end of the membrane array to the PX device, to the booster pump, then to the feed end of the membrane array. There are connection points on the PX unit labeled “HP IN” (concentrate from the membrane array) and “HP OUT” (pressurized feedwater leaving the PX unit going to the booster pump for additional pressurizing). HP IN is labeled “G” on Figure 1. HP OUT is labeled “D” on Figure 1. The flow path from the concentrate outlet of the membrane array into the PX unit at “G”, out of the PX unit at “D”, through the booster pump, into the membrane array along with the feedwater from the high pressure pump (HPP) and through the membrane array again exiting as concentrate is the high pressure flow circuit. The high-pressure flow circuit can be viewed as a closed loop with the type of water changing due to the action of the PX unit. The pressure sensed at “G” will be the concentrate pressure and the pressure sensed at “D” will be the concentrate pressure minus the small loss through the PX unit. The booster pump will add back the circuit pressure losses and will deliver pressurized feedwater to the membrane at the same pressure that is produced by the HPP.

Lubrication Flow – The internal mechanism of the PX Pressure Exchanger device – the ceramic components of the PX unit that perform the transfer of energy – are lubricated by high-pressure water from the high-pressure flow circuit. This lubrication flow allows the rotor to float almost frictionless on a hydrodynamic bearing. The lubrication fluid is always being renewed during operation. New lubrication fluid flows from the high-pressure flow circuit, through the ceramic assembly and out to the drain via low-pressure flow path. As the PX unit high-pressure flow rate is set and constant, the lubrication fluid must be provided by the system HPP. The volume of lubrication fluid required varies with membrane feed pressure, temperature and the overall flow rate through the PX unit. The higher the membrane feed pressure, the greater is the volume of lubrication fluid required.

Balanced Flow – ERI recommends that the PX unit LP flowrate and the PX unit HP flowrate be controlled – set equal - to within 5.0% for optimum SWRO operation. When the flows are balanced, the operator will see that the conductivity of the seawater measured at (D) will be slightly higher than the seawater measured at (B). To achieve balanced flow through the PX

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unit, ERI requires that flow meters be installed in both the PX unit HP flow circuit and in to PX unit LP flow path. If possible, it is best to install the flow meters in the low-pressure inlet and high-pressure outlet lines (seawater) or the low-pressure outlet and high-pressure inlet (brine reject) lines. Operating the PX unit with a HP flow rate higher than the LP flow rate will result in contamination of the seawater feed by the brine reject which may reduce permeate quality, increase feed pressure and increase energy consumption. Operating the PX unit with a LP flow rate higher than the HP flow rate will waste LP feed water and lower overall plant efficiency.

Mixing – Because the transfer of energy within the PX unit is accomplished by putting the high-pressure brine reject into direct contact with the low-pressure seawater feed, there is some contamination of the seawater at the interface with the brine. The PX unit is designed to operate at fluid mixing levels at or below 6 percent. Balancing flows helps limit mixing. At balanced flows and 40 to 45% recovery, the salinity of the seawater measured at (D) is approximately 3.5% higher than the salinity of the seawater measured at (B). When the HP flow rate is greater than the LP flow rate, the mixing will be higher. When the LP flow rate is higher than the HP flow rate, the mixing will be lower but will never reach zero mixing. Measuring and comparing the conductivity of the seawater at (B) and (D) on a regular basis is a good system check.

PX Technology Basics versus the Conventional SWRO - Required Information

Permeate Production

When designing a system using the PX technology, the volume of permeate produced will be roughly equal to the volume of feed water pumped by the high-pressure pump (HPP). Unless you have the ability to increase or decrease the flow rate through the HPP, you cannot change the volume of permeate produced. There is no reject control valve – a common component in conventional SWRO systems. Increasing the system operating pressure alone will not increase the volume of permeate produced. If the system HPP is a centrifugal pump, high membrane feed pressures will drive the flow back on the curve and the permeate flow will be decreased.

Recovery

As stated above, the flow rate at the HPP output equals the flow rate of permeate produced. The PX unit HP flow circuit supplies concentrate. Therefore, the membrane recovery is calculated using the combined HP flow rate. Normally, the PX unit LP flow is adjusted to equal the PX unit HP flow so the system recovery will equal the membrane recovery. If the LP flow rate is higher than the HP flow rate, the overall system recovery will be less than the actual membrane recovery. The operator can change the recovery rate by adjusting the PX unit flows as long as the PX unit flow rates remain within the specified flow range of the PX units. Making changes in the HPP flow rate, if possible, can also change the recovery rate.

Pressure control

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The operating pressure of a system that uses the PX unit is determined by the salinity and temperature of the feed water, the membrane system design and the membrane condition. The system operating pressure will be the pressure that is required to pass the output of the HPP through the membrane as permeate. There is no reject control valve to open or close to set and maintain the system operating pressure. The PX unit flows must be controlled as they can affect the feed water salinity. Improperly adjusted PX unit flow rates can affect system operating pressures.

The PX unit requires approximately 15 psi or 1 bar backpressure. Backpressure lower than specified by ERI may cause cavitation and damage to the ceramic assembly. Conversely, higher backpressures will reduce the possibility of cavitation.

There is a pressure drop across the LP side of the PX unit during normal operation. This pressure drop varies with flow rate but will be a maximum of about 12 psi or 0.8 bar. The SWRO system design should provide adequate LP feed pressure to achieve the desired LP flow rate, overcome the pressure drop across the PX unit and still satisfy the backpressure requirement. In a system with a well-designed LP supply, a minimum of 27 psi or 1.9 bar of supply pressure is required at the PX unit(s).

There is a pressure drop across the high-pressure side of the PX unit that also depends upon flow rate. This pressure drop, along with the pressure drop across the membrane array plus the calculated pressure losses in the high pressure circuit piping, should be estimated and used when sizing the booster pump. Pressure drop versus flow rate curves for each PX device model are available from ERI.

Flow Control

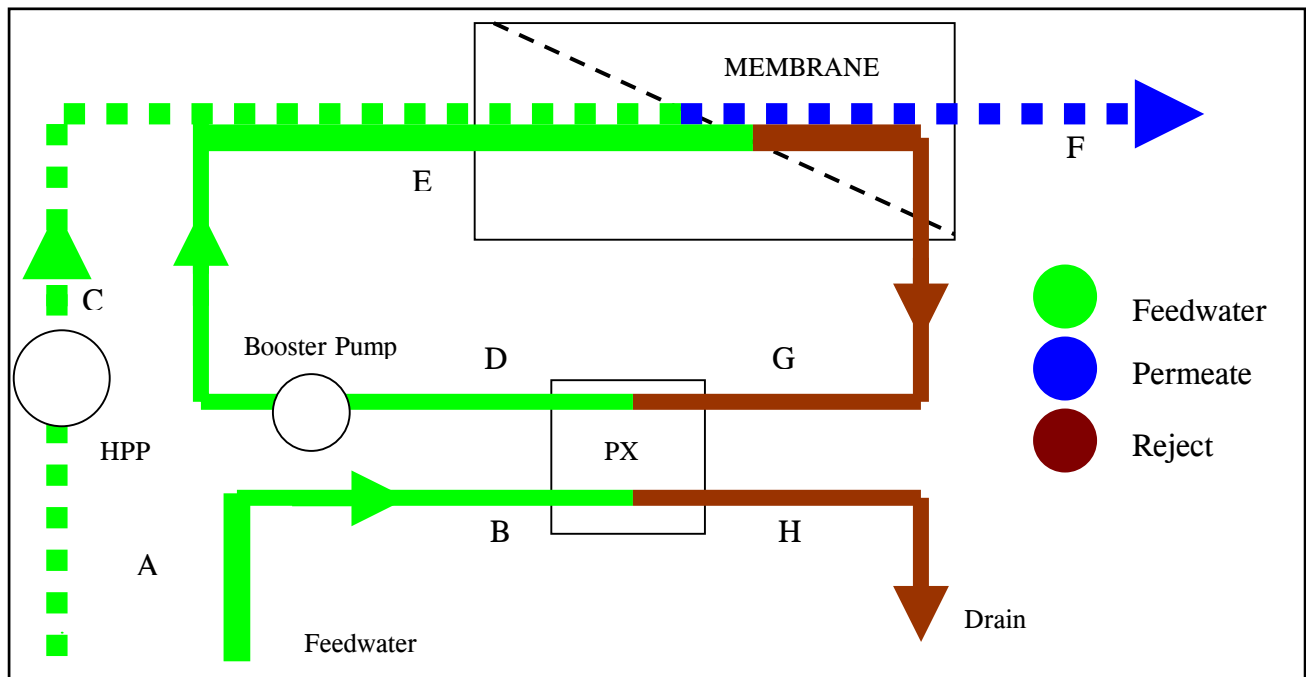
Three flow rates must be considered in a system built around the PX energy recovery device – the high-pressure flow rate through the PX device, the low pressure flow rate through the PX device and the flow rate through the HPP. The two flow rates through the PX unit must remain within the specified limits at all times – during start-up, normal operation, flushing, cleaning and shutdown. High flow rates can damage the internal components of a PX unit. Low flow rates may result in excess mixing. The three flows are entirely independent of each other – changing one does not affect the others. All must be measured and controlled independently.

High Pressure Pump (HPP) Flow – The HPP flow path is illustrated with a dashed line in Figure 3. The flow rate of pressurized feed water to the membranes determines the permeate flow rate. Therefore, care must be exercised when specifying the HPP capacity and/or some means to change the pump flow rate must be installed. A variable frequency drive (VFD) can be used or sheaves and belts can be changed on PD pumps to change the flow rate. Permeate flow from the system is usually metered and it can be beneficial to measure the feed water flow to the HPP. The permeate flow will less than the feed flow to the HPP by the lubricant flow rate through the PX device hydrodynamic bearing.

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PX Unit High Pressure (HP) Flow – The PX unit internals are constructed in such a manner as to isolate LP from HP. It is important to understand that changing the LP flow rate will not affect the HP flow rate or vice versa. With reference to Figure 1 or 2, imagine that there are two pieces of straight pipe inside the PX unit – one carrying the LP flow from “B” to “H” and another one carrying the HP flow from “G” to “D”. Because the flows are contained in separate pipes, they are isolated. Flow meters must be installed on each flow circuit.

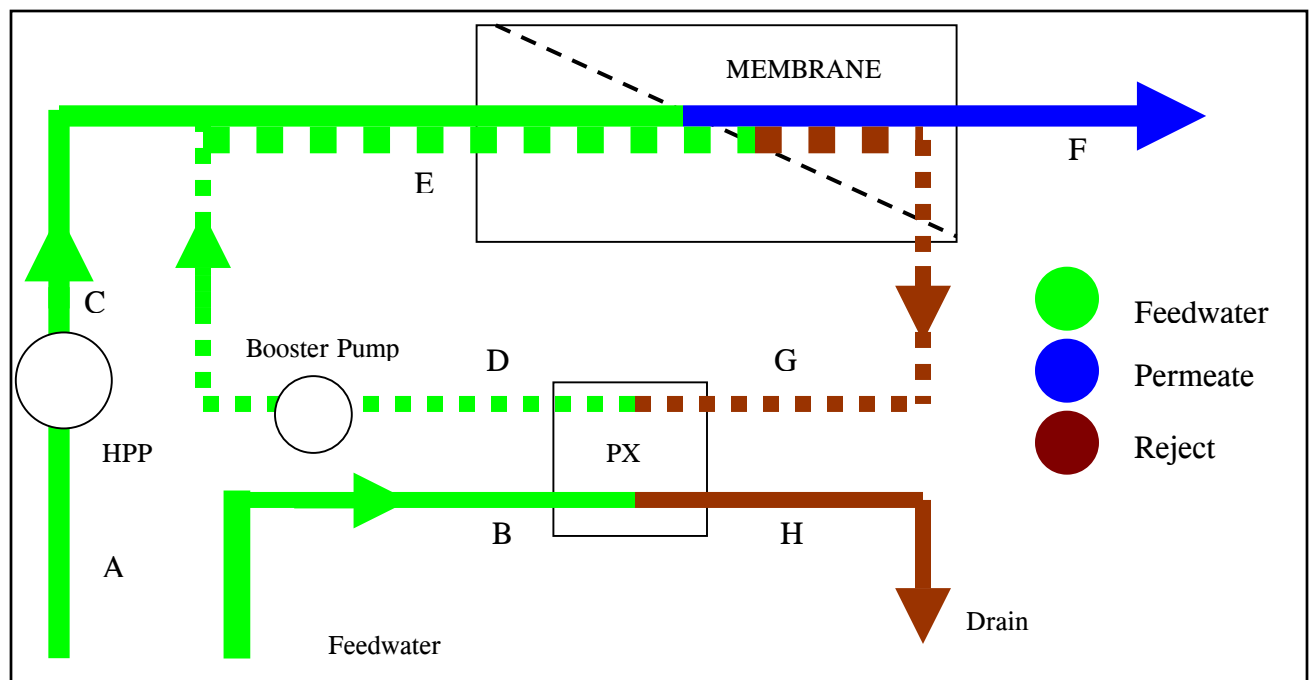
Figure 3 – High Pressure Pump (HPP) Flow Path



The flow of high-pressure water from the membranes to the PX device to the booster pump and back to the membranes can be considered a closed loop. The HP flow circuit is illustrated with a dashed line in Figure 4. Pressure is lost to friction in the membranes, piping and in the PX unit. The booster pump is necessary in most applications to re-pressurize the flow from the PX unit so that it can enter the membrane feed stream. The booster pump must be sized to make up the pressure losses at the required flow rate. This flow rate is relatively easy to control using a VFD on the booster pump or a control valve downstream from the booster pump. A flow meter is required in this flow circuit.

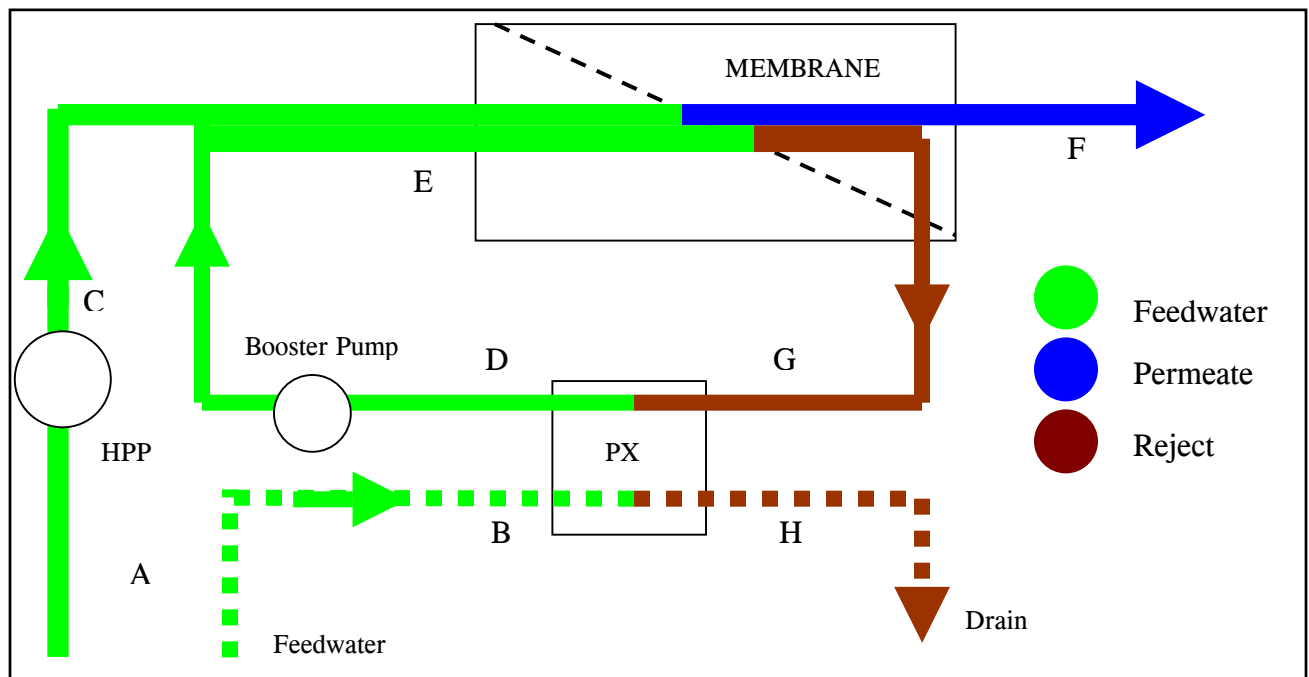
PX Unit Low Pressure (LP) Flow – The flow rate of low pressure water to the PX unit and out to the brine waste is usually set to equal the PX unit HP flow rate. The LP flow path is illustrated in Figure 5 with a dashed line. By changing this flow rate, the operator can slightly alter the salinity of the membrane feed. If the LP feed water pressure can be controlled and held constant, LP flow control can be accomplished with a high quality manual valve installed downstream of the PX unit and upstream of the brine disposal point. It is not always easy to hold the feed water pressure constant. Often, the LP feed water to the PX unit and the HPP feed water come from the same source making it more difficult to maintain a constant PX unit LP feed water pressure, especially when starting the system, during flushing or when more

Figure 4 - PX Unit High Pressure Flow Circuit



than one train is being fed from the same feed water header system. Although not always practical, the best and safest design (as drawn above) is to have the PX unit LP feed water come from a dedicated source (pump, tank, etc.) and control the flow with a valve downstream of the PX unit. A flow meter is required in this flow path.

Figure 5 - PX Unit LP Flow Path



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System Components

The following list provides a summary of important SWRO and PX unit components, features and considerations.

Piping

- PX unit port connectors are fabricated from alloy AL-6XN (a very similar alloy to 254 SMO). They have standard flexible coupling grooves. Mating piping should be compatible. Galvanic corrosion can occur where incompatible materials are used.
- Piping connections to the PX unit must be designed to minimize stress on the PX unit port connections. The vessel must bear the weight of the PX unit, not the ports.
- The maximum operating pressure of the PX unit is 1200 psig.
- Where multiple PX units are installed in an array, piping manifolds should be designed to provide equal flow to and from each PX unit (see ERI Technical Bulletin “Isobaric Device Flow Performance in Arrays – How does the SWRO Plant Designer and Operator Control Flow?”).
- 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 particles greater than 5 microns in diameter into the PX unit and void the warranty.

Supports

- The PX unit vessel must be supported independent of piping connections. Piping and headers should be supported independent of the PX unit. The PX unit ports must not bear the weight of the piping.
- The PX unit does not create vibration. There are no special foundation requirements.
- The booster pump should be mounted per the manufacturer’s instructions.

Instrumentation

- ERI requires that flowmeters be installed in both the PX unit HP flow circuit and the PX unit LP flow path. It is important that the flowmeters be installed per manufacturer’s instructions. Even an expensive flowmeter installed incorrectly will not be accurate.
- ERI suggests that high flow alarms/shutdowns be incorporated into the system design to protect the PX unit from potential damage by high flows. Protect your PX unit with flow meters just as you would protect your pumps with low pressure switches on the suctions.
- ERI suggests that a pressure gauge be installed downstream of the PX unit to measure the backpressure.
- ERI suggests that each plant have a hand-held conductivity instrument and that sample points be installed as indicated on ERI’s recommended PX unit installation process and instrument diagrams. Comparing the conductivity of the LP IN water to the HP OUT water will indicate whether or not flows to the PX unit are balanced. Checking and comparing the LP OUT conductivity of each PX unit on systems with multiple PX units is a good troubleshooting tool.

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Operational Information

- Allowable flow ranges for individual PX unit models are listed in the ERI's Installation, Operation and Maintenance Manuals and product literature. PX units are not designed to operate outside of these ranges.
- Seawater feed to the PX unit must be filtered to 10 microns or less and should be treated as required by the SWRO membrane manufacturers.
- The PX device vessel enclosures (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 a PX unit.
- The PX unit must never be exposed to temperatures less than 33 deg F [1 deg C] or greater than 113 deg F [45 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 150 psig (6.9 bar). The minimum discharge pressure from the PX unit shall be 15 psig (1.0 barg).
- 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 unit.
- Some chemical additives are known to be the cause of operational failure of PX devices. These chemicals include, but are not limited to polyacrylates, occasionally used for scaling prevention. If incorrectly applied, these chemicals can cause PX unit failure by forming a sticky substance that can physically jam the PX device mechanism.
- System piping must be flushed completely clean prior to flowing through the PX unit. Construction debris can damage the internal components of the PX device.

Conclusion

We hope that this information is clear and that you are now equipped to move forward and begin using the PX Pressure Exchanger energy recovery device as part of your SWRO and BWRO systems. Please feel free to call Energy Recovery to discuss anything you are not clear about. We encourage our customers to forward their system P&IDs to ERI for review. Our goal is to help our customers be successful.

Remember, manuals and other literature are available on the ERI website along with pictures of installations of various sizes and configurations. ERI technical personnel are available to assist with any questions.

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