

Energy Recovery, Inc.

Development of a Fourth Generation Energy Recovery Device

Richard L. Stover, Ph.D.

EDS MARRAKECH

JUNE 2, 2004

Outline

- *History of Energy Recovery Devices*
- *4 Generations of Pressure Exchangers*
- *PX Operation*
  - *Mixing*
  - *Lubrication*
  - *Efficiency*
  - *Multi-PX Arrays*
- *SWRO-PX Systems*
  - *Design Considerations*

The Pressure Exchanger (PX)

Isobaric chamber work exchanger / energy recovery device

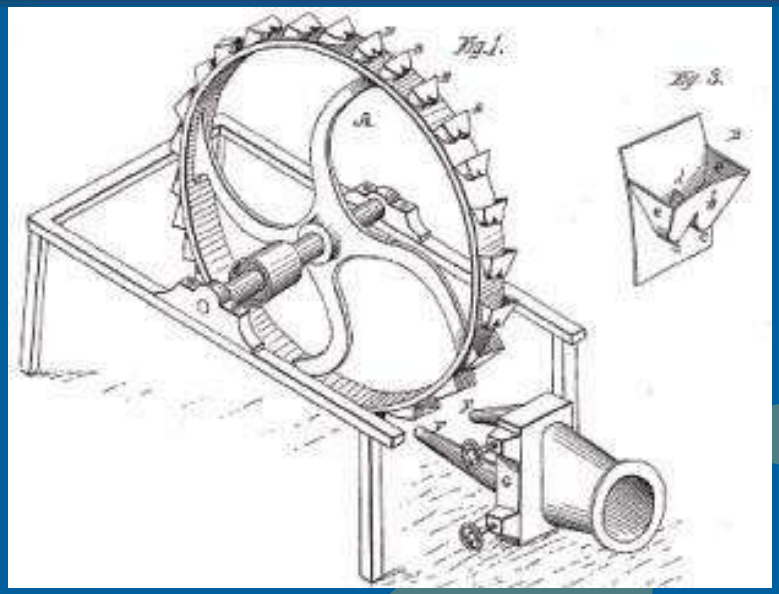
pressure transfer from brine reject to seawater feed



Prior Art

Pelton Wheel

- Pelton 1883
- hydraulic energy → nozzle → turbine → (impeller → hydraulic energy)
- Flow-driven operation.



Turbocharger

- 1910, Oklejas 1990
- hydraulic energy → turbine → impeller → hydraulic energy
- Water lubricated bearing.

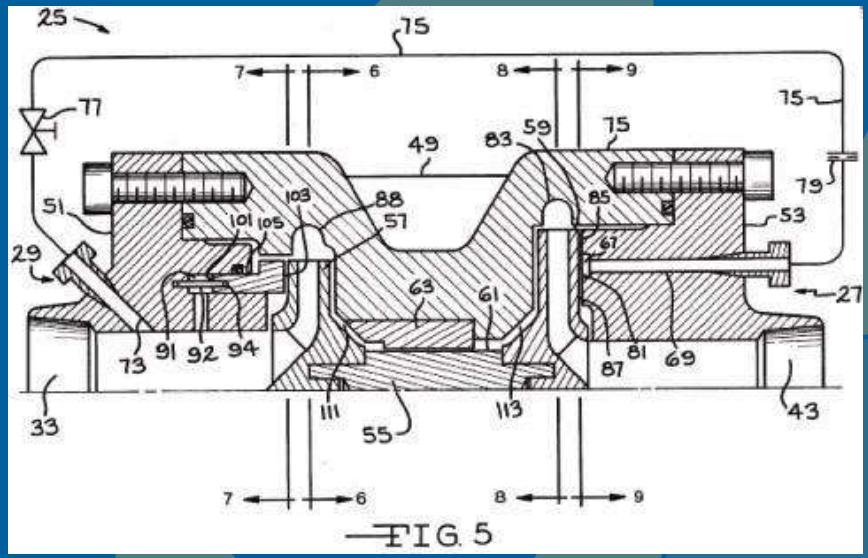


FIG. 5

Prior Art

Piston Work Exchanger

- Cheng 1970 (Aqua Design 1985
- hydraulic energy → hydraulic energy
- Positive displacement – highest efficiency

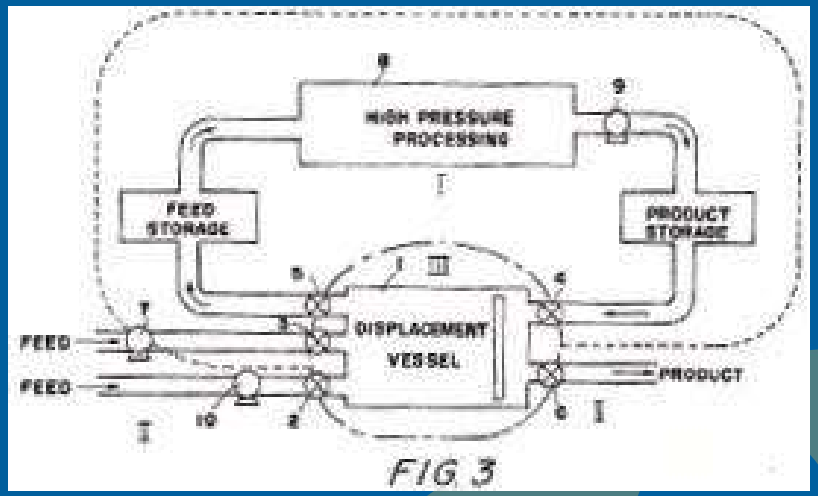
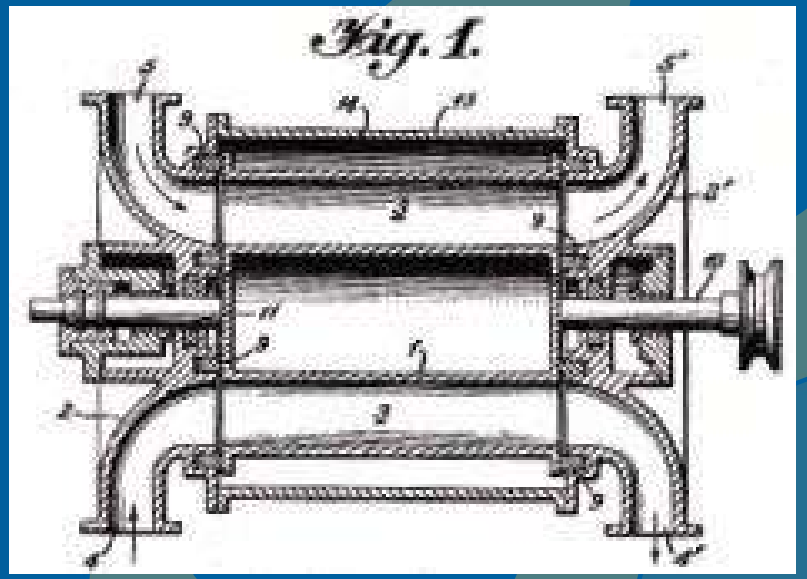


FIG 3

Rotary PX

- Jendrassik 1954
- hydraulic energy → hydraulic energy
- One moving part



PX Development

Metal Rotor: 1st Generation

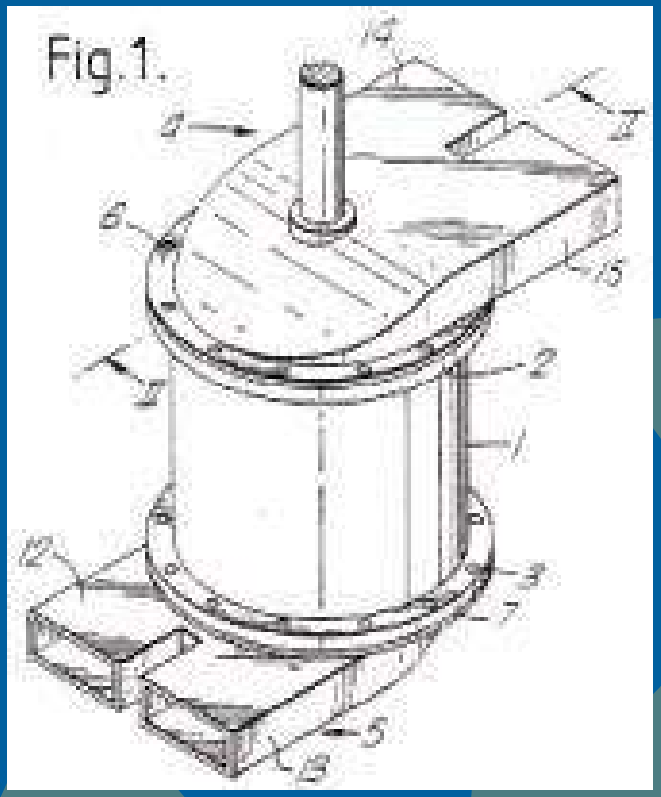
- Hauge 1989
- Galling
- Ramp endcovers – flow driven rotation

Ceramic Rotor: 2nd Generation

- Hauge 1997 (1999)
- Hydrodynamic bearing

4-inch Series: 3rd Generation

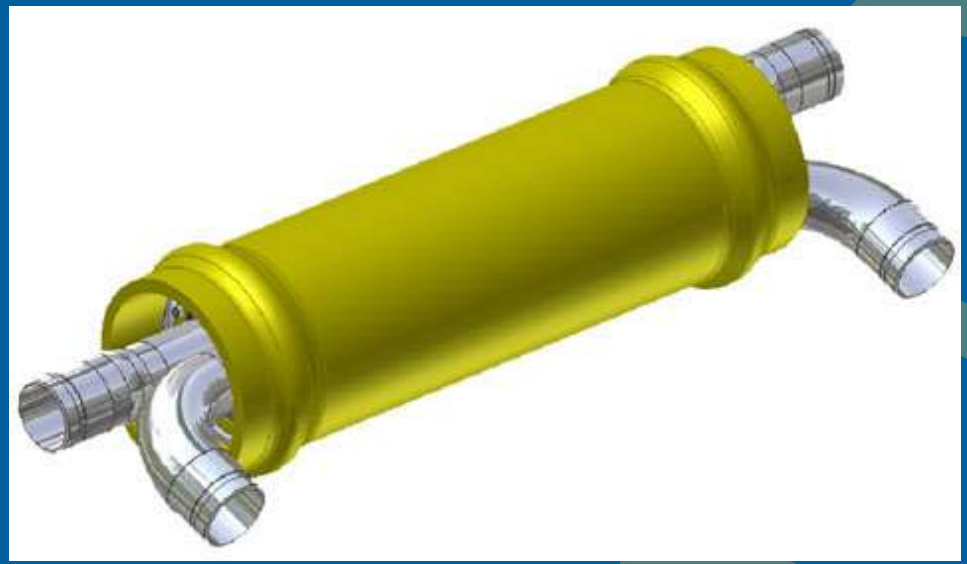
- Hauge 1998, ERI 1999
- Smooth pressure transitions



PX Development

65-Series, 4S-Series: 4th Generation

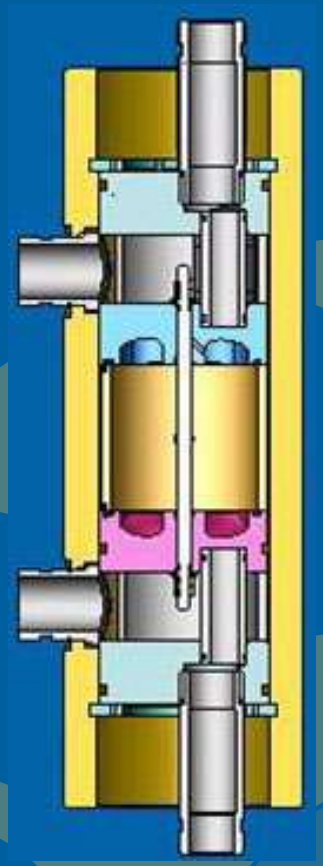
- ERI, 2003
- Up to 50 m^3/hr (220 gpm) per rotor
- Standard vessel and connections
- Smoother pressure transitions



The Pressure Exchanger (PX)

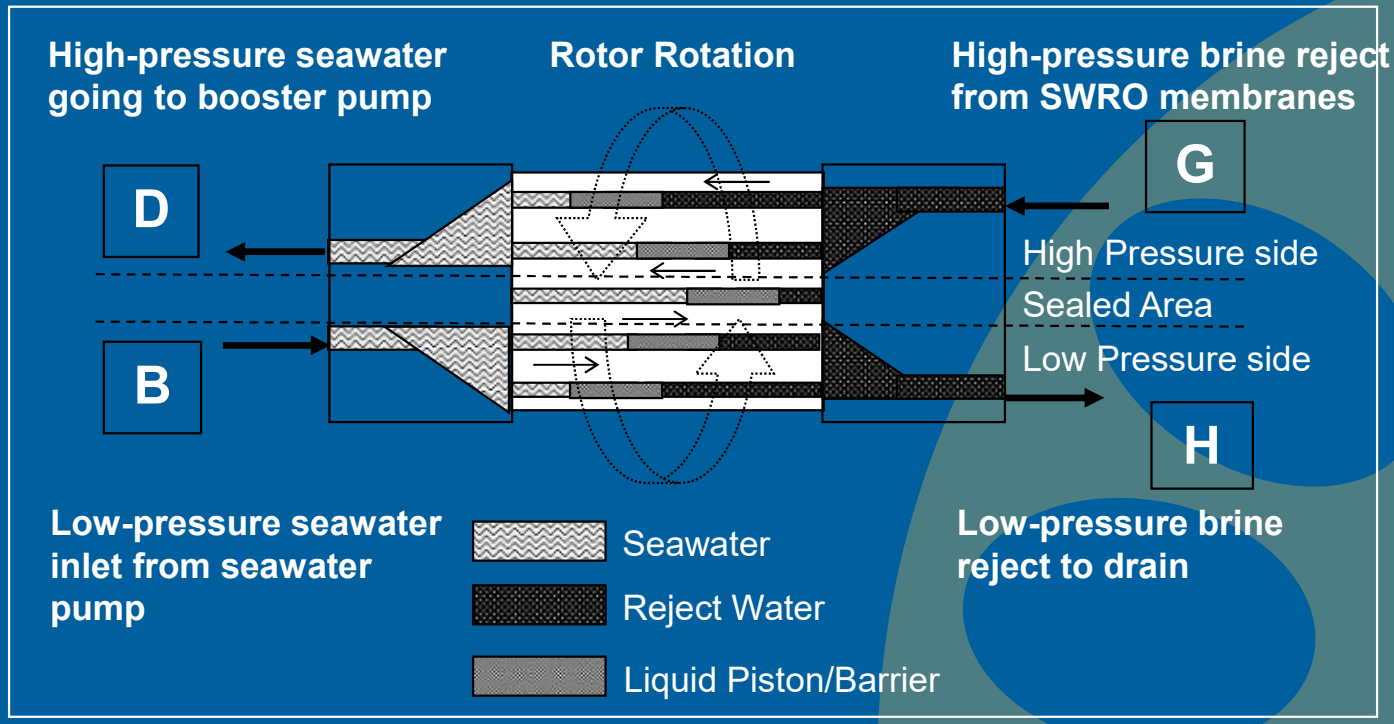
FEATURES

- Positive displacement *(highest efficiency).*
- Flow-driven operation (*no external drives*).
- Water-lubricated hydrodynamic bearing.
- Ceramic components (*no wear, tight tolerances*).
- One moving part (*no valves, pistons or controls*).
- Standard vessel (*easy service*).
- Smooth pressure transitions (*controlled pulsations, cavitation, water hammer*).



How the PX Works

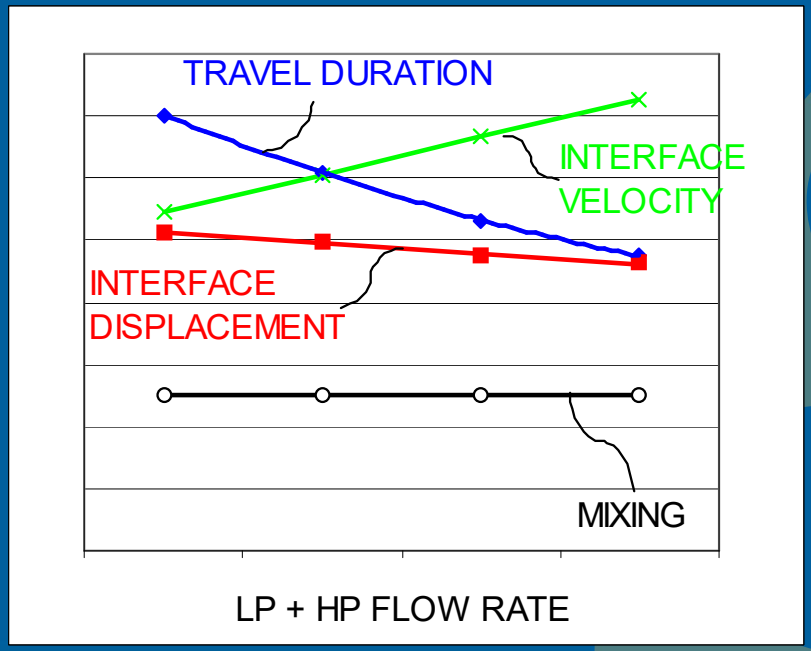
- High-pressure brine compresses low-pressure seawater
- Waste brine ejected by fresh seawater
- Sealed area between high- and low-pressure
- No physical barrier at the liquid interface



PX Mixing

Flow rate controls rotor speed

- B-SW interface velocity increases with flow rate.
- Travel duration decreases with rotor speed / frequency.
- Interface displacement approximately constant.
  - PX designed so displacement is less than rotor length.
- Mixing constant over flow range.



PX Efficiency

- Pressure-transfer efficiency:

$$efficiency = \frac{\sum (Pressure \times Flow)_{OUT}}{\sum (Pressure \times Flow)_{IN}} \times 100\,\%$$

- PX: 94 to 97%

  hydraulic energy → hydraulic energy

- Pelton wheel: 80% maximum

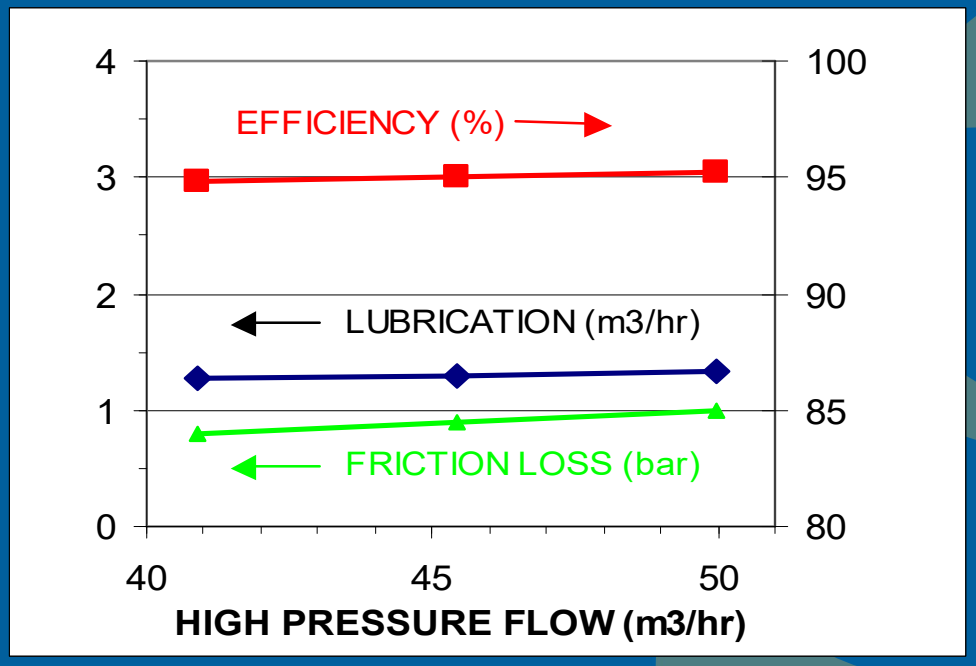
  hydraulic energy → nozzle → turbine → impeller → hydraulic energy

- Turbocharger: 80% maximum

  hydraulic energy → turbine → impeller → hydraulic energy

PX Efficiency

- 95% efficiency = 5% efficiency loss
  - 1% lost to the compression
  - 2% is lost to viscous friction, including rotor torque
  - 2% goes to lubrication flow
- Overall efficiency vs flow constant

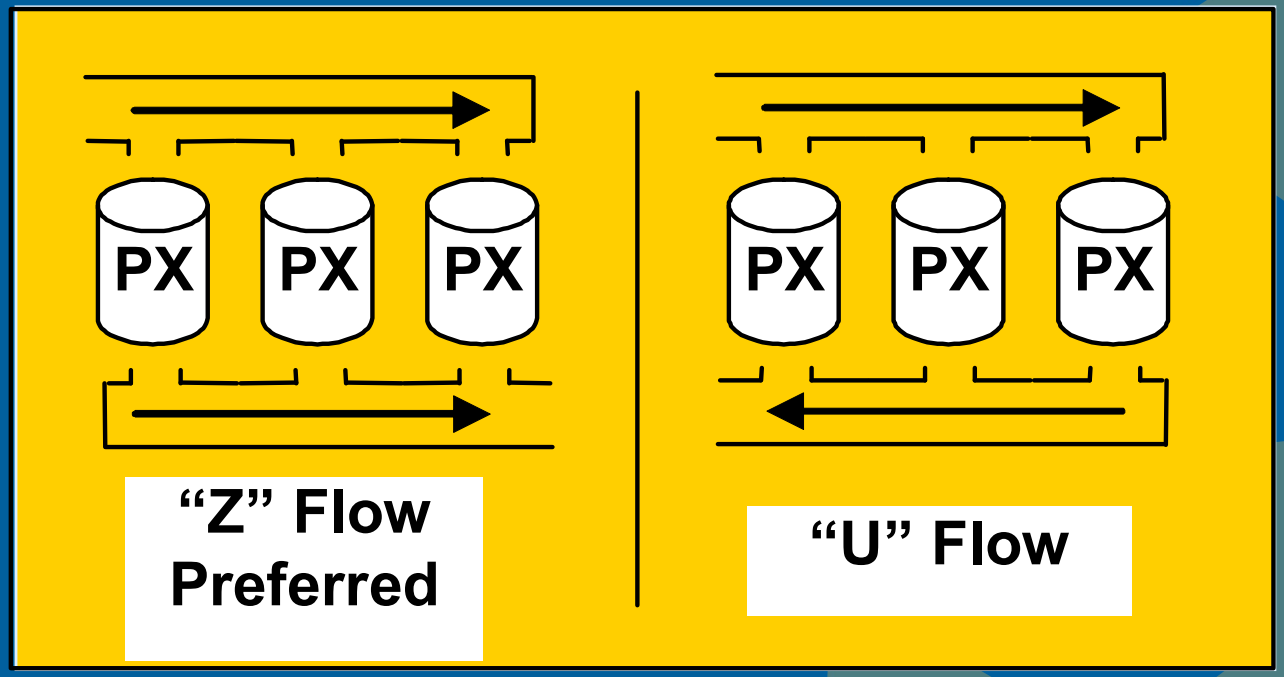


Multiple-PX Arrays

BALANCING FLOW THROUGH PX ARRAYS

- PX manifolds – same as membrane manifolds.
- Orient manifolds for co-current or “Z” flow.
- Design manifold for low pressure drop.

Figure 3 – Manifold Flow Schemes



Multiple-PX Arrays

- Multi-PX arrays running for years.
- No resonance.
- Even flow distribution.
- Flow through stuck rotor = flow through turning rotor

Figure 9 – 12 PX-120 Array

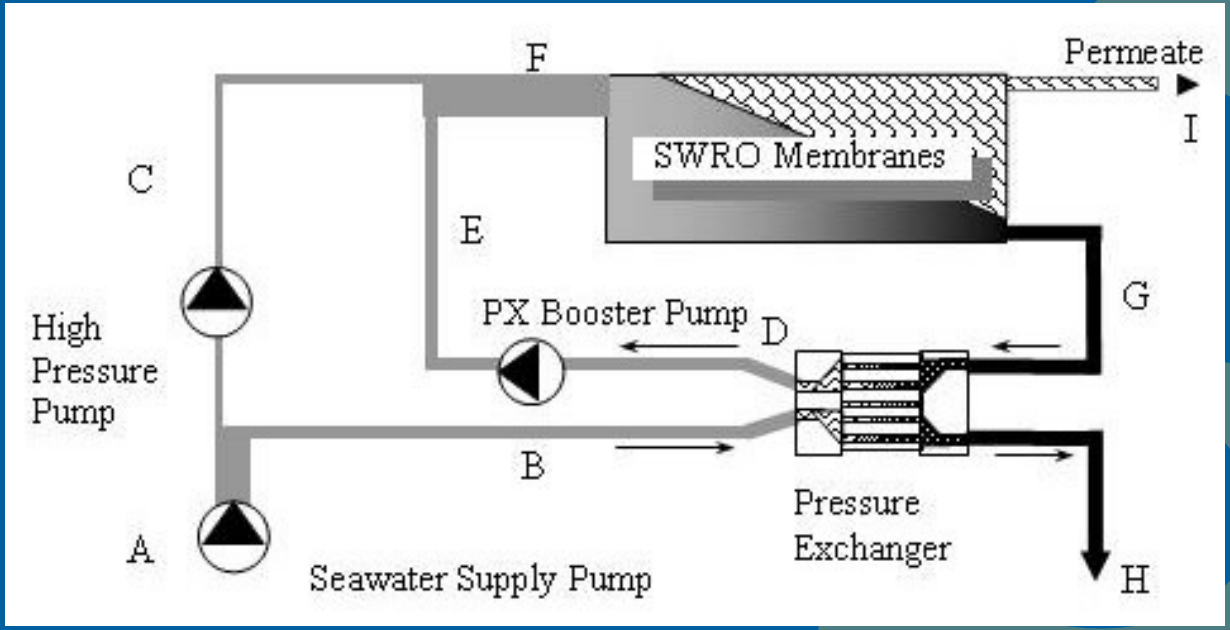


Figure 10 – 10 PX-220 Array



SWRO-PX Systems – Flow Control

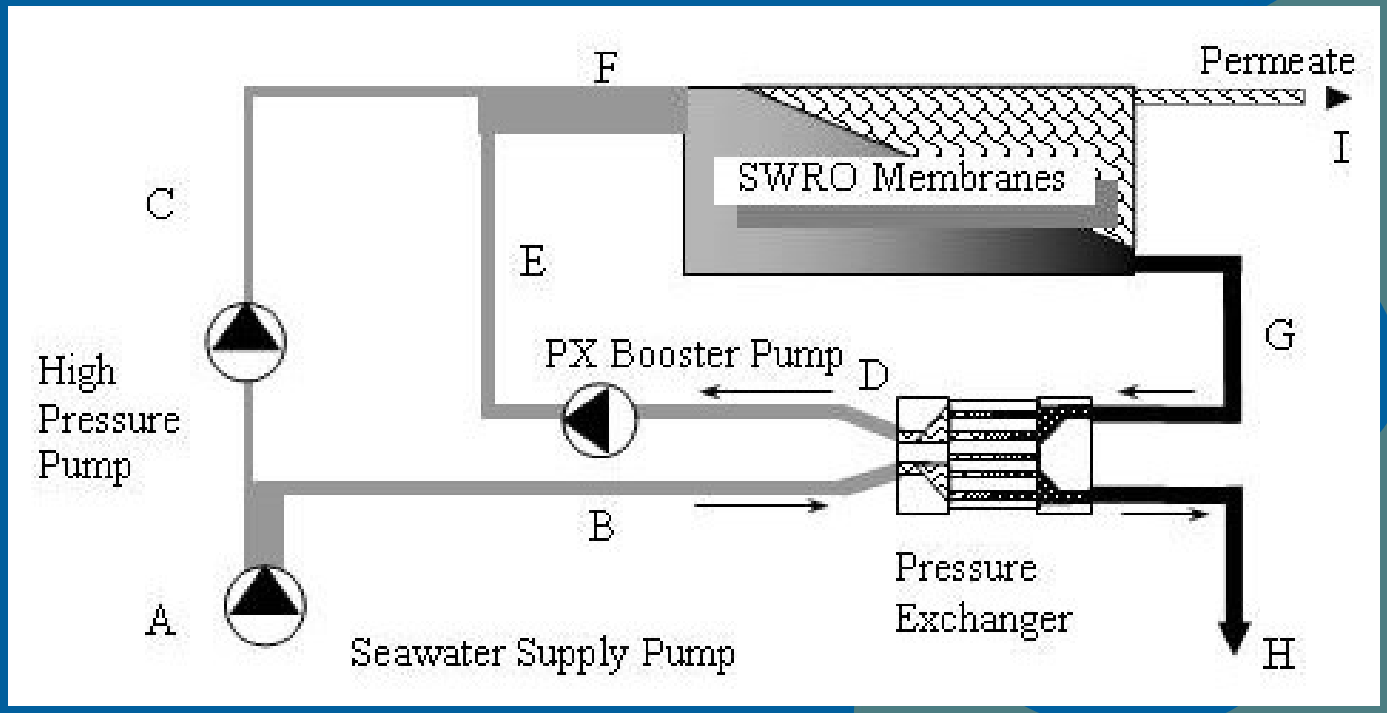
- The PX works like two parallel pipes.
- High-pressure: membranes → PX → booster pump → membranes.
  HP flow rate controlled by the booster pump.
- Low-pressure: supply pump → PX → discharge.
  LP flow rate controlled by discharge valve.
- High- and low-pressure flows are independent.
- Flow meters required in both high- and low-pressure lines.



SWRO-PX Systems – PX Lubrication

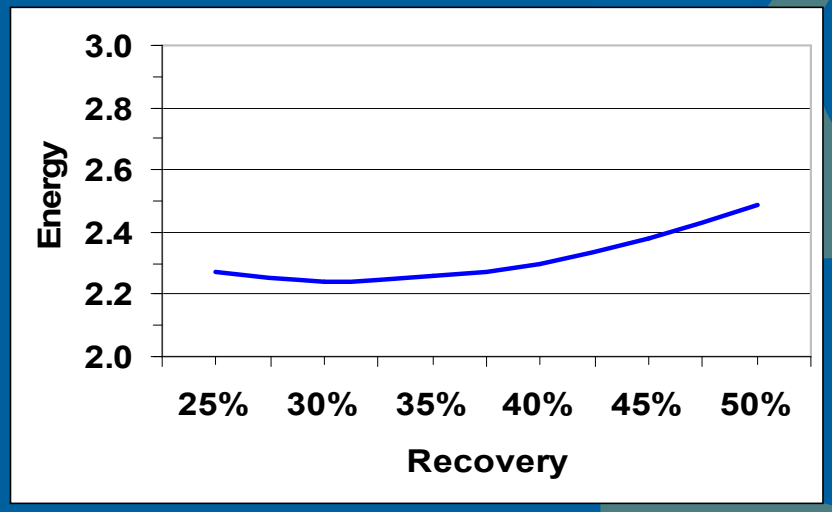
High-pressure water flow through hydrodynamic bearing

- Lubrication = HP pump – permeate
- Lubrication = PX HP in – PX HP out
- Lubrication = PX LP out – PX LP in
- HP pump = permeate + lubrication



SWRO-PX Systems – PX Mixing

- Volumetric mixing at balanced flow = 6%
- Salinity increase = 2.5%
- Operating pressure increase = 1.3 bar
- Operator Options:
  - **Accept pressure increase (2°C feed temp)**
  - **Decrease recovery by 2% by increasing HP/LP flow**
  - Add 6% more membrane surface, or use LE membranes
  - Increase low-pressure supply to the PX by 5%



SWRO-PX Systems – Design

1. Permeate Rate: Establish the required permeate rate.
2. Operating Pressure: Estimate membrane operating pressure based on feed salinity, percent recovery.
3. HP Pump: High-pressure pump capacity = permeate rate plus PX lubrication.
4. Number of Membranes: Based on permeate rate and recovery rate.
5. PX Capacity: PX capacity = membrane reject rate plus optional additional capacity of 5 - 10%.
6. Booster Pump – Booster pump capacity = membrane reject rate minus PX lubrication.

PX Product Line

The PX is available in the following sizes:

PX Model Number	Capacity (m^3/hr)	Capacity (gpm)
PX-220	41 – 50	180 – 220
PX-180	32 – 41	140 – 180
PX-140 (NEW!)	20 – 32	90 – 140
PX-90 (NEW!)	14 – 20	60 – 90
PX-70 (NEW!)	9 – 16	40 – 70
PX-45 (NEW!)	6 – 10	25 – 45
PX-25	3 – 6	15 – 25
PX-15	2 – 3	10 – 15