American Membrane Technology Association

Affordable Desalination Collaboration

AMTA/ADC Pre-Conference Workshop

Desalination Technology Developments & Improvements

Austin, TX – July 13, 2009

Latest Developments in Pumps and Energy Recovery

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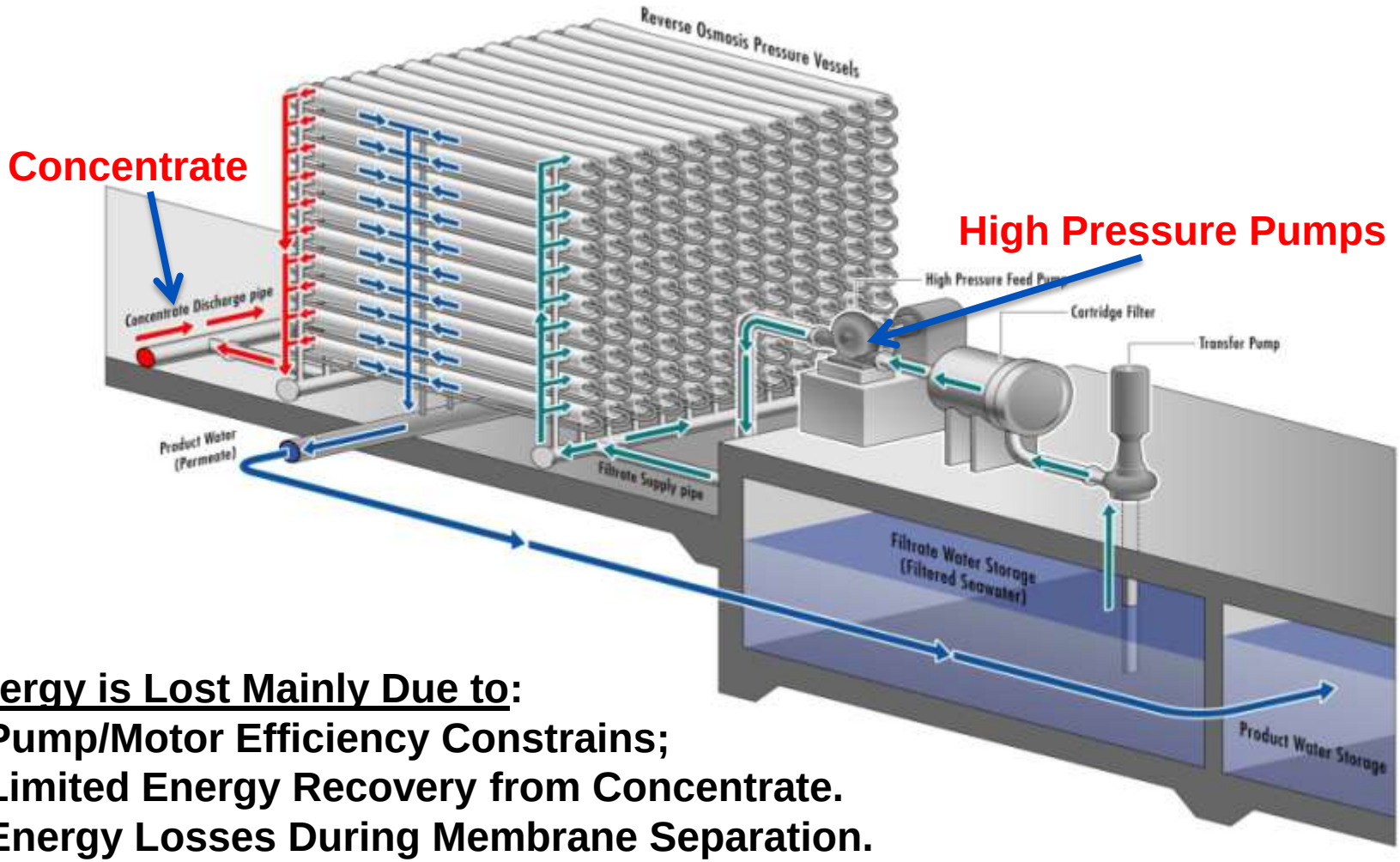
Presentation Overview

- **High Pressure Pumps – Technology Trends;**
- **Energy Recovery Technologies – Present and Future.**

75% to 85% of Desalination Plant Energy Used by the SWRO System



Energy is Lost Mainly Due to:

- **Pump/Motor Efficiency Constrains;**
- **Limited Energy Recovery from Concentrate.**
- **Energy Losses During Membrane Separation.**

Types of SWRO High Pressure Pumps

- **Reciprocating (Positive Displacement/Piston) Pumps;**
  - **Applications Typically Limited to 1.0 MGD;**
  - **90 % to 95 % Efficiency;**
  - **Flat Pump Curve – Efficiency and Flow Constant at Changing Membrane Pressures.**
- **Centrifugal Pumps:**
  - **Available in All Sizes;**
  - **82 to 88 % Efficiency;**
  - **Pump Efficiency Varies with Changing Membrane Pressure.**

Positive Displacement (Piston) Pumps – Key Features

- **Fixed Flow Independent of Pump Operating Pressure.**
- **Rotating Motion of the Motor is Converted to Reciprocating Motion to Drive the Pistons.**
- **Delivered Capacity Fluctuates with:**
  - **Number of Pistons;**
  - **The Area of the Pistons;**
  - **Stroke Length;**
  - **Operating Speed – Often Run at ½ Speed to Reduce Maintenance (Reduces Efficiency to 80 – 85 %);**

Piston Pumps – Flow Variation & Control

- **All Piston Pumps Deliver Pulsating Flow;**
- **Flow Pulsation (Difference between Min and Max Flow) Depends on the Number of Pistons:**
  - **2 Pistons – 46 %;**
  - **3 Pistons – 23 %;**
  - **7 Pistons – 4 %;**
  - **9 Pistons – 2 %.**

CAT triplex pump

- **Installation of Multiple Pumps with Common Suction Header Typically Creates Severe Vibration Problems – Suction Stabilizers and Pulsation Dampeners – A Must!**

Centrifugal Pumps

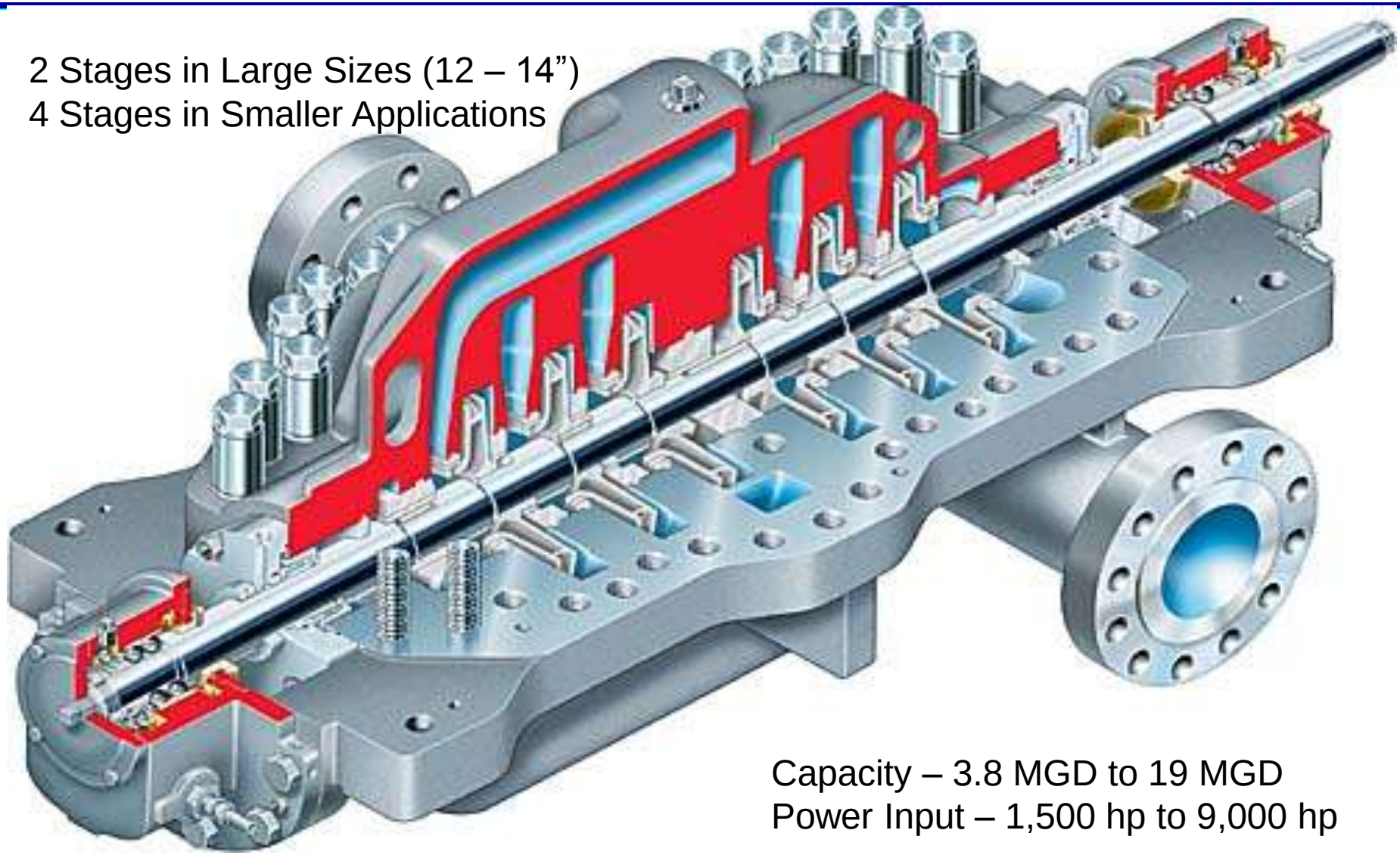
- **Horizontally Split-case Multistage Pumps:**
  - Most common for large applications (>1,000 gpm);
  - Typically Yield Highest Efficiency (80 – 88 %).
- **Segmental Ring (Ring-section) Multistage Pumps:**
  - Unit flow rates – 350 to 1,000 gpm;
  - Popular for Medium Feed Flows – lower costs at reasonable efficiency.
- **High-Speed Single-Stage Pumps:**
  - Typically Used for Small Plants (50 gpm – 600 gpm);
  - Often Combined w/ Turbochargers.

Horizontally Split-Case Multistage Pumps

- **Casing Split in two Pump Halves;**
- **Seawater Guided from Stage to Stage by Set of Volute Passageways;**
- **Opposing Impeller Design – Allows to Reduce Net Axial Trust;**
- **Larger, More Rugged, More Expensive Than Segmental Ring Pumps.**

Horizontally Split-Case Pumps

2 Stages in Large Sizes (12 – 14”)
4 Stages in Smaller Applications



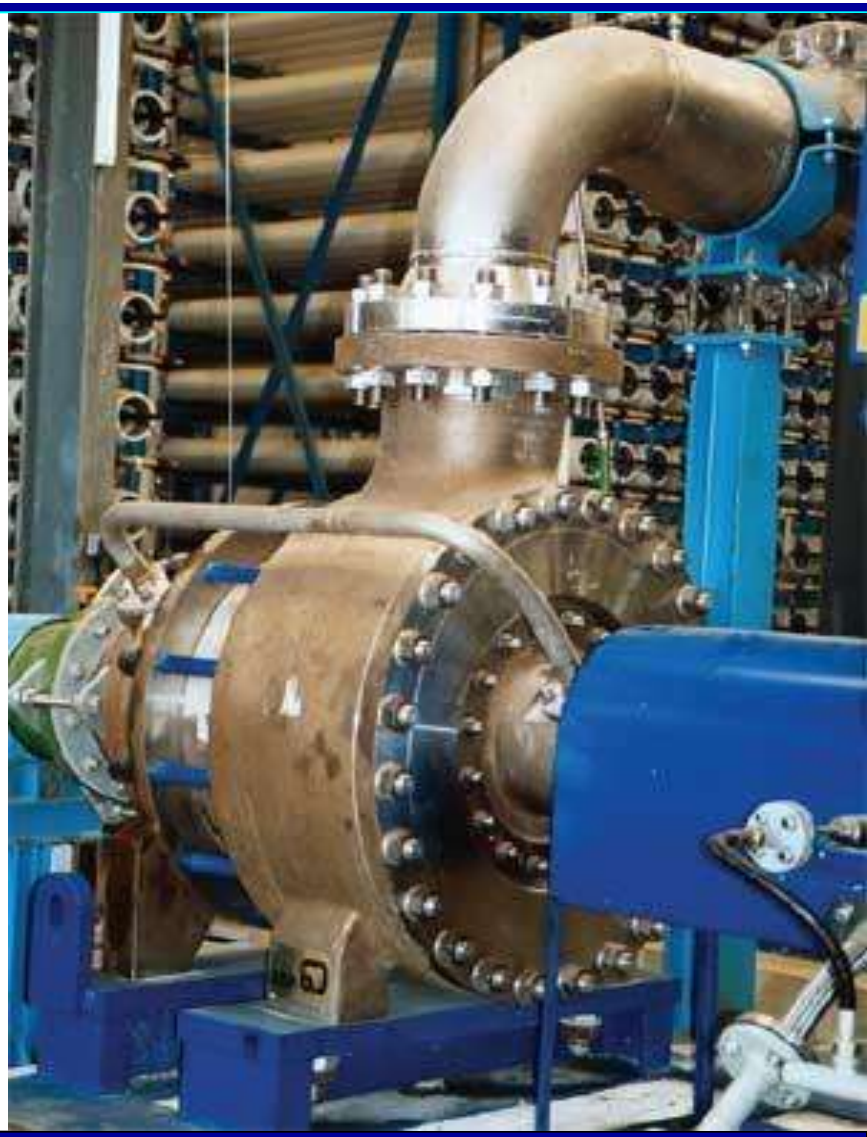
Capacity – 3.8 MGD to 19 MGD
Power Input – 1,500 hp to 9,000 hp

Ashkelon - Largest High Pressure Pumps In Use Today

- Two Sets of 3+1 Two-stage Horizontal Split-case Pumps – 16 MGD each;
- Pump Motors – 7,000 hp;
- 5-year Pump Efficiency Guarantee;
- All Wet Parts Made of Duplex Stainless Steel.

Radially Split Case Pumps

- Occupy Less Space;
- Easier to Maintain;
- Less Vibrations;
- Only One Mechanical Seal of the Drive End (Axial – 2 seals);
- Internal Fiber-Composite Bearings (Water Lubricated) – vs. External Grease Lubricated;
- Largest Pumps Installed for Expansion of Dhekelia SWRO Plant (Cyprus) to 10.5 MGD;
- Unit Capacity – 7.0 MGD (2,800 hp) – 87 % Efficiency.



Radially Split High Pressure Pumps will be Used in Sydney, Australia

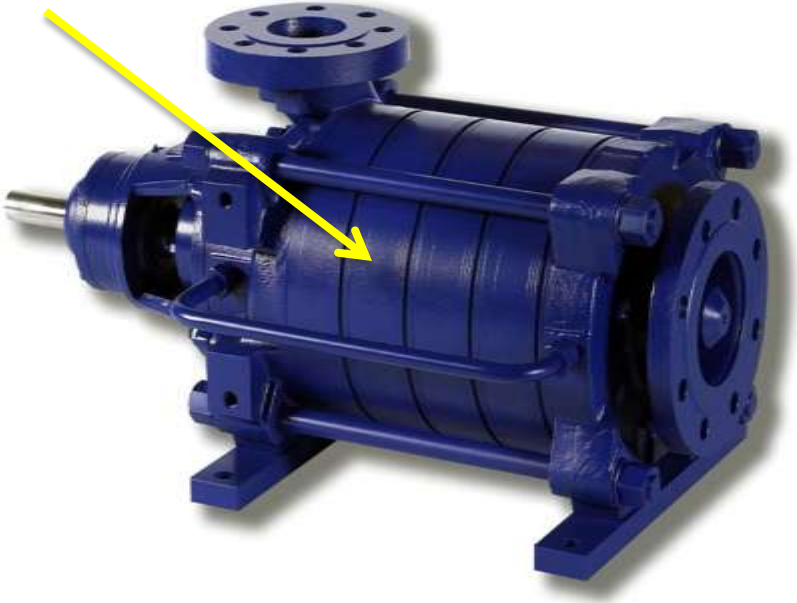
Sydney SWRO Plant

12+1 KSB
HP HGM-RO 8/3 Pumps
2,000 KW each
87 % Efficiency

One Pump per SWRO Train

Segmental-Ring Pumps

- **Individual Pump Stages Located Between Pump Suction and Discharge Casings;**
- **Impellers Mounted on Common Shaft;**
- **Smaller Diameter;**
- **Lighter Construction;**
- **Lower Cost.**



Centrifugal Pumps – Key Considerations

- **Pump Efficiency Increases with Square Root of Speed for the Same Flow;**
- **Speed – typically 3,000 to 3,500 rpm (up to 12,000 rpm);**
  - **Shaft size and required NPSH increase with Speed;**
  - **Limit Pump Speeds to 3,500 rpm.**
- **Pump Curve Flattens with Increase of Number of Stages;**
- **Pump Efficiency Increases with Flow for the Same TDH.**

Maximizing Pump Efficiency – Bigger Pumps Rule!

- **Pump Efficiency ~**

$$n \times (Q/H)^{0.5} \times (1/H)^{0.25}$$

Where:

n = pump speed (min^{-1});

Q = nominal pump capacity (m^3/s);

H = pump head (m).

Pump Efficiency:

One Pump Per Train – 83 %;

One Pump Per 2 Trains – 85 %;

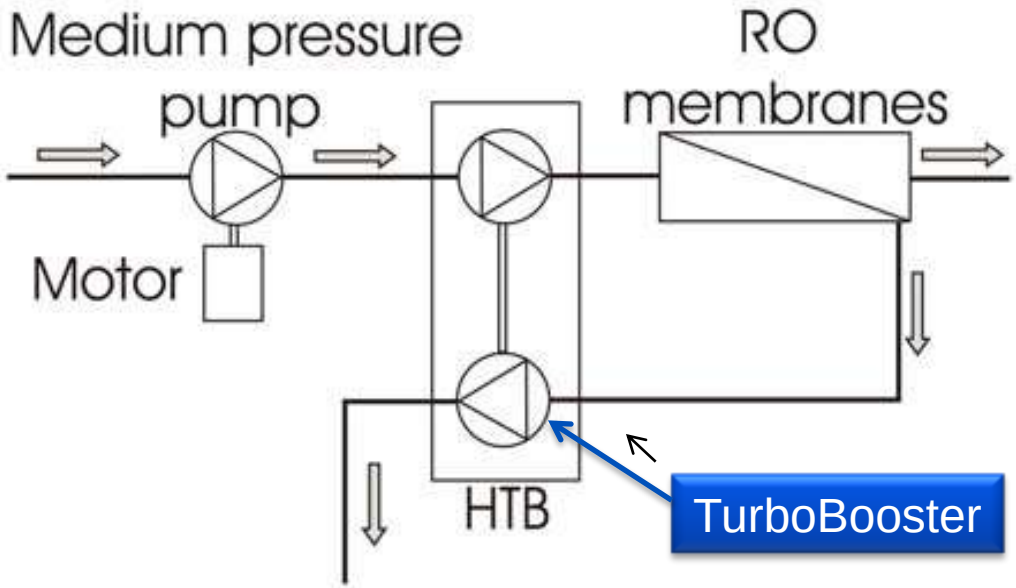
Three Pumps Per 16 Trains – 88 %.

Carboneras, Spain –
One Pump per 2 RO Trains

Ashkelon, Israel –
(3+1) 7,100-hp Pumps per 16 RO Trains

Maximizing Energy Recovery

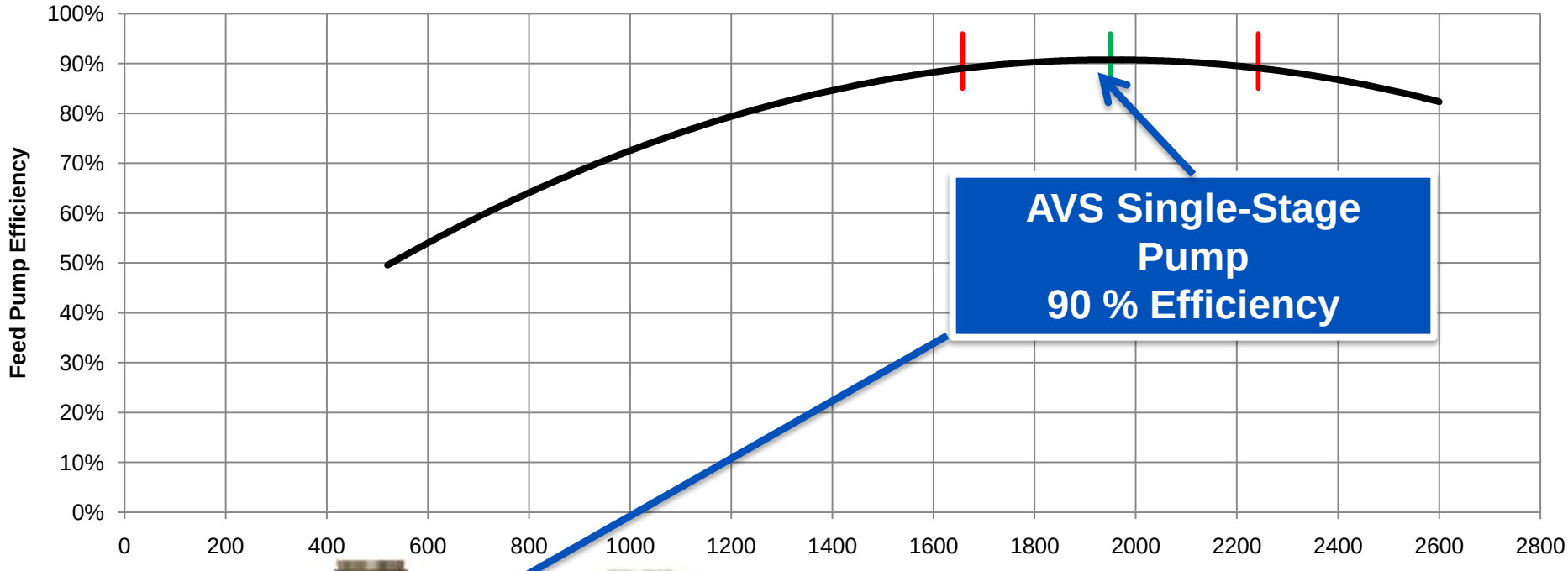
Hydraulic Turbocharger



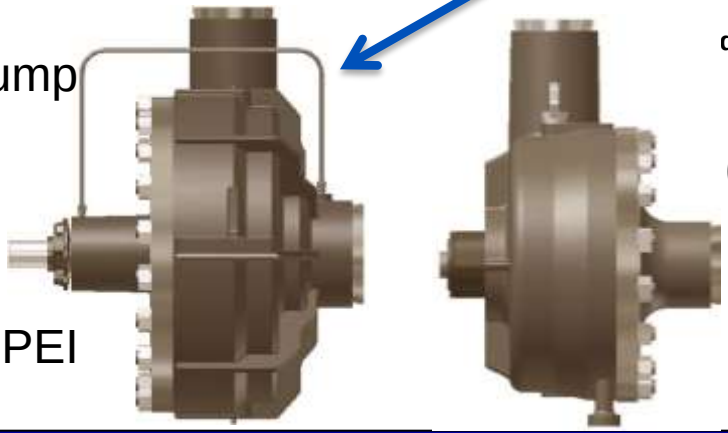
Courtesy: PEI

- **Turbocharger Popular for Small and Medium Size Plants (20 to 40 % pressure boost).**
- **Available for Low & High Pressures.**
- **Used for High-Recovery (Brine Conversion) Systems to Achieve 60 – 65 %.**
- **Low Maintenance & Brine Leakage Into Feed Stream.**
- **Lower Cost and Space Requirements than Other Energy Recovery Systems.**

Energy Recovery System Incorporates Pump of Improved Efficiency



AVS Pump



ER Turbine (88 to 90 % efficient)

Courtesy: PEI

Typical Energy Recovery Efficiency 75 to 80 %

Hydraulic Turbocharger – Large Installations (8.9 to 10 kWh/kgal)

Pump Efficiency ~
$n \times (Q/H)^{0.5} \times (1/H)^{0.25}$

- **30 MGD Plant in Jebel Ali, UAE:**
  - **9 RO Trains;**
  - **16 Single-stage HP RO Pumps.**
  - **Up to 525 psi of Boost;**
  - **HP RO Pumps Operating @ Full Flow @ ½ Pressure –**

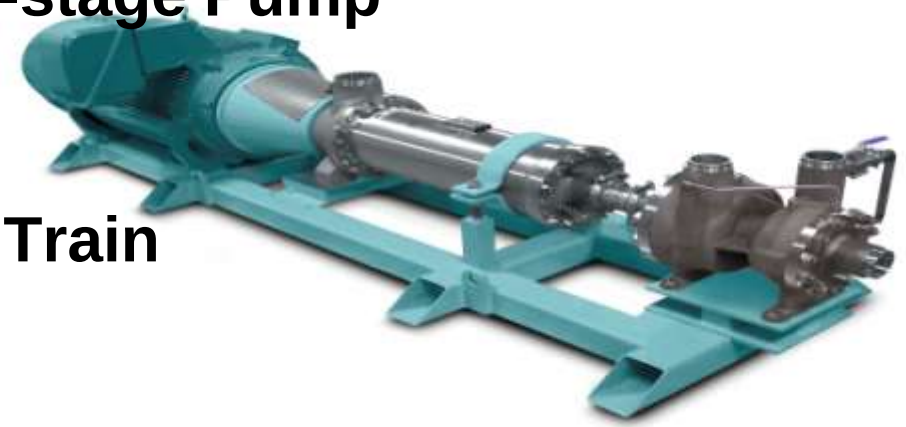
    5-7 % Extra Efficiency.
- **9.2 MGD Plant in Thailand (PT Chemicals) - 10 kWh/kgal.**
- **38 MGD NEWater Ulu Pandan Plant, Singapore**

Turbocharger – Next Steps

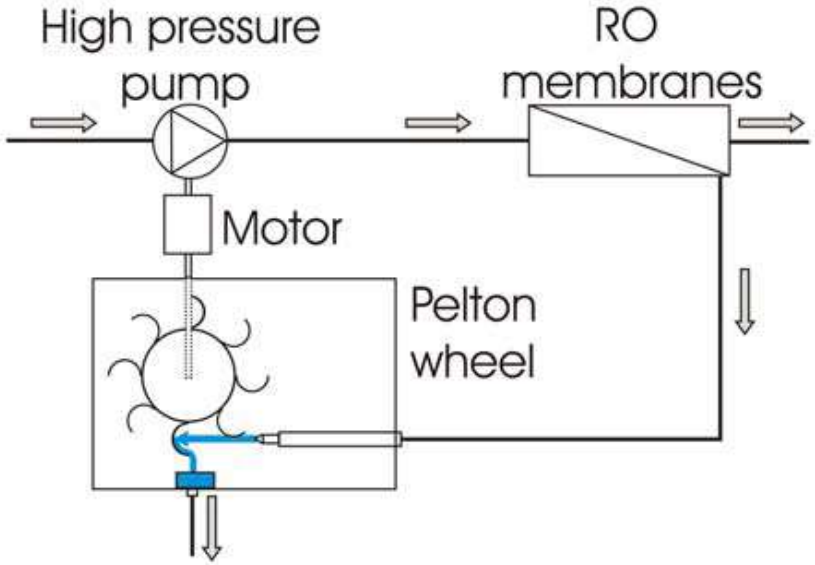
- **Centralized Brine Energy Recovery, Brine Pressure Flow, and Pressure Control;**
- **Elimination of Feed Throttle Control Valves, VFDs on the HP Pumps and Brine Pressure Control Valves.**
- **Combination w/ Single-stage HP RO Pump of High Efficiency for Capacities of Up to 12.7 MGD of Feed.**
- **Combination w/ Large Multi-stage Pump**

  (4,200 gpm) –

  Can Feed 2.5 to 3 MGD RO Train



Pelton Wheels – Majority of Existing Plants



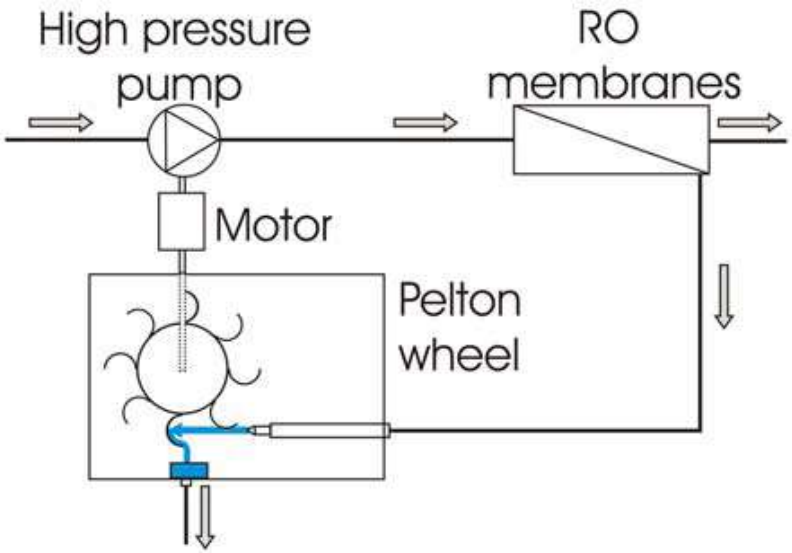
Conversion Efficiency: 80 to 90 %

Pelton Wheels Limit Individual RO Pump Size to 5.5 MGD

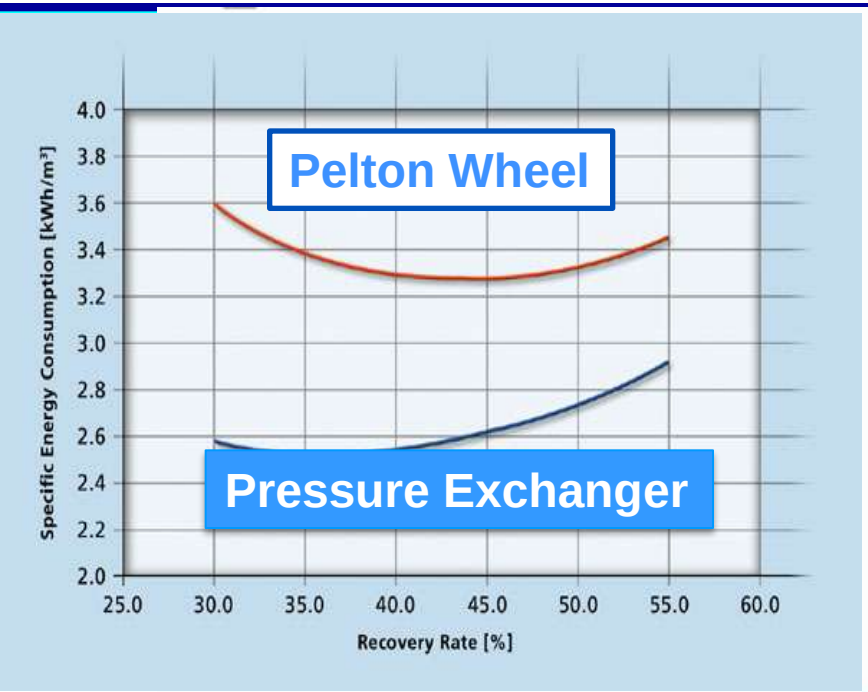
Trinidad SWRO Pump and Pressure Exchanger System – The Largest in the World

Key Limitation of Pelton Wheel Technology on Pump Efficiency

- Couples Pump and Energy Recovery System



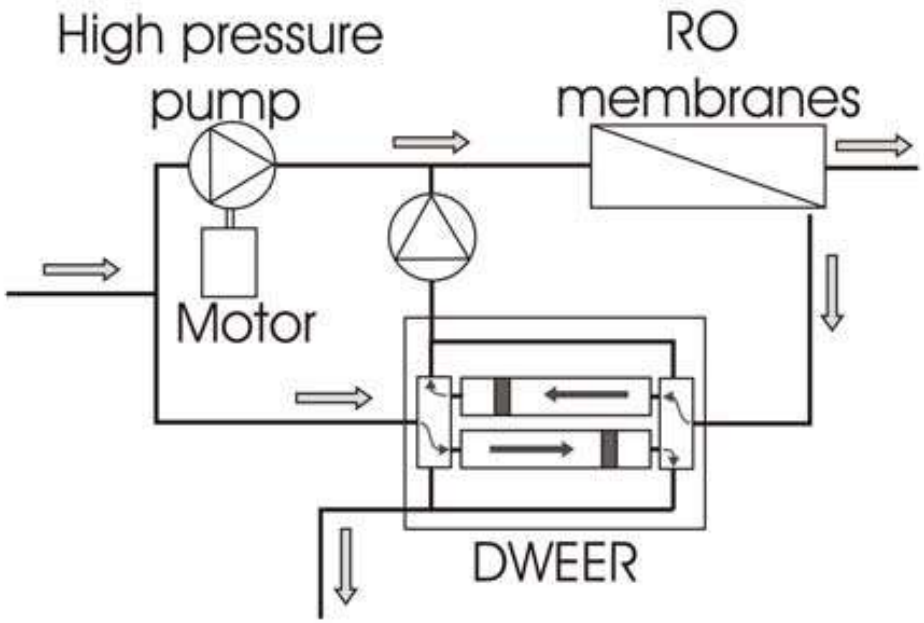
Pressure Exchangers Allow the Use of Larger Pumps/RO Trains



Provides 2 % of the Energy

Provides 40 - 42 % of the Energy

DWEER and ERI Pressure Exchangers

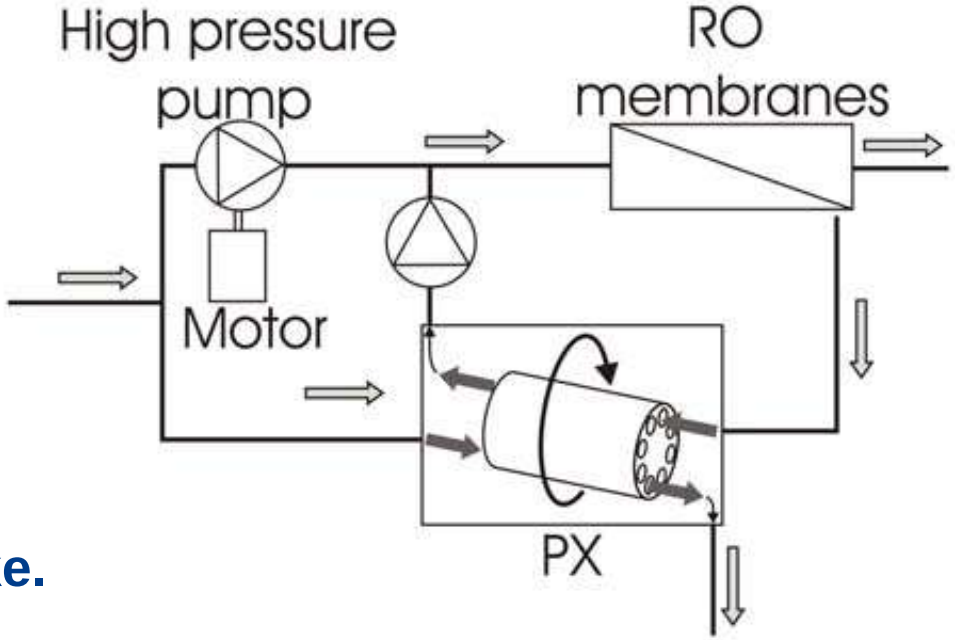


DWEER Exchanger

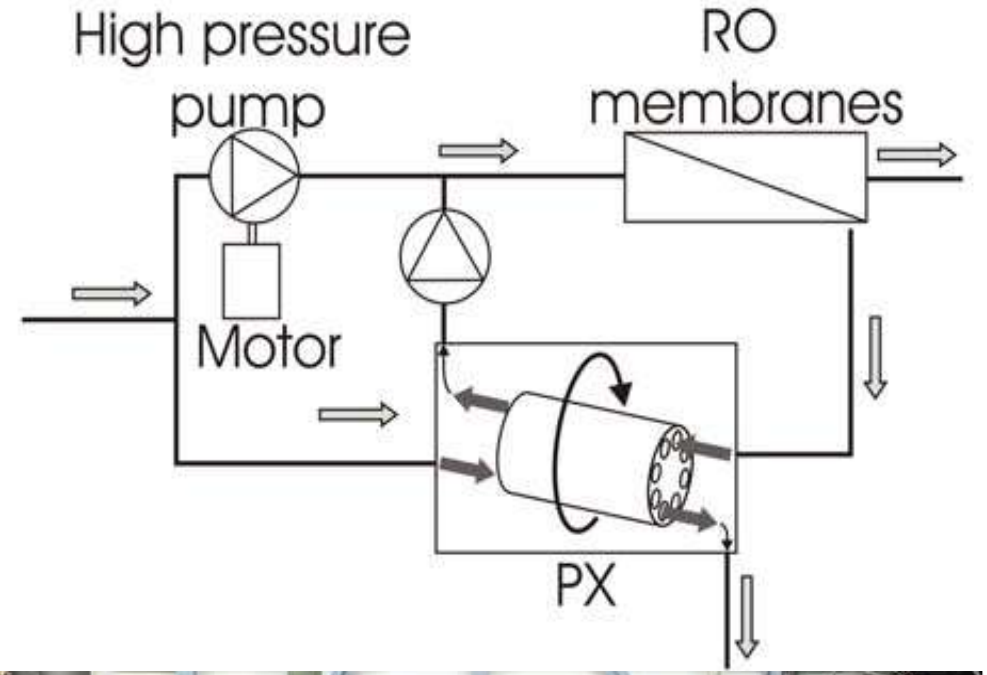
- Positive Displacement Pistons Instead of Rotor;
- LinX Valves Cause the Two Vessels to Exchange Functions before The Piston Completes Stroke.

ERI PX Pressure Exchanger

- 96% Energy Conversion Eff.
- Smaller Footprint;
- One Moving Part – Shaftless Rotor;
- Rotor Hydrostatically Suspended in Ceramic Sleeve.



ERI System – Current Status



- **Largest In Operation - Hamma (Algeria) – 50 MGD;**
- **Largest in Construction – Hadera (Israel) – 72.3 MGD;**
- **Base Unit – PX 220;**

  (0.3 MGD) in ops since 2002;
- **10 to 16 Units per RO Train (2.5 MGD – 4 MGD RO Train).**
- **Challenges:**
  - **Mixing – 5 to 7%**
  - **Efficiency Decreases w/ Increase in Plant Recovery.**

Perth SWRO & Pressure Exchanger Systems

ERI – New Energy Recovery Equipment

- **PX 260**

- 18 % Larger Capacity than PX220;

- Wider Flow Paths to Higher Throughput @ Minimum Pressure Losses.

- **Titan 1200**

- 500% Larger Capacity than PX220;

- Similar Overall Energy Recovery (Slightly Lower Efficiency Compensated by Lower Mixing);

- Side-ported Design Allows to Maximize Flow Production.

Courtesy: ERI

ERI System – Titan 1200

- **Can Handle 5 Times More Flow than PX 220 (1.4 MGD of Brine Flow);**
- **16-inch Protec Pressure Vessel;**
- **Energy Efficiency – 96.6 %;**
- **Reduced Mixing of Brine Feed and Leakage – from 6 % to 2.3 %;**
- **Testing Continues @ 4.6 MGD Los Cabos SWRO Facility, Mexico;**
- **Market Release Planned for 2010.**

Courtesy: ERI

ERI Equipment – What is in the Pipeline?

- **CompPX - SWRO**
  - **8-inch Vessels Similar to PX 220 & PX 260**
  - **Side-ported design**
  - **Maximized Production.**
- **PX-240 – Brackish Water RO**
  - **For Brackish RO Applications**
  - **Target Efficiency @ 90 % Under Brackish RO Pressures (<450 psi)**
  - **Currently Operating on Facility in Turkey.**

DWEER System – Current Status

- **Used in Ashkelon (86 MGD) and Singapore (34 MGD);**
- **1.3 MGD SWRO Train – One DWEER System – Model 1100;**
- **Ashkelon – 2 x 40 DWEER 2200 Systems;**
- **RO w/ DWEER - 2.0 to 2.5 kWh/kgal Less Energy than Pelton Wheel (45 % Rec.).**

Tuas, Singapore
Triple DWEER 1100
3.6 MGD SWRO Trains

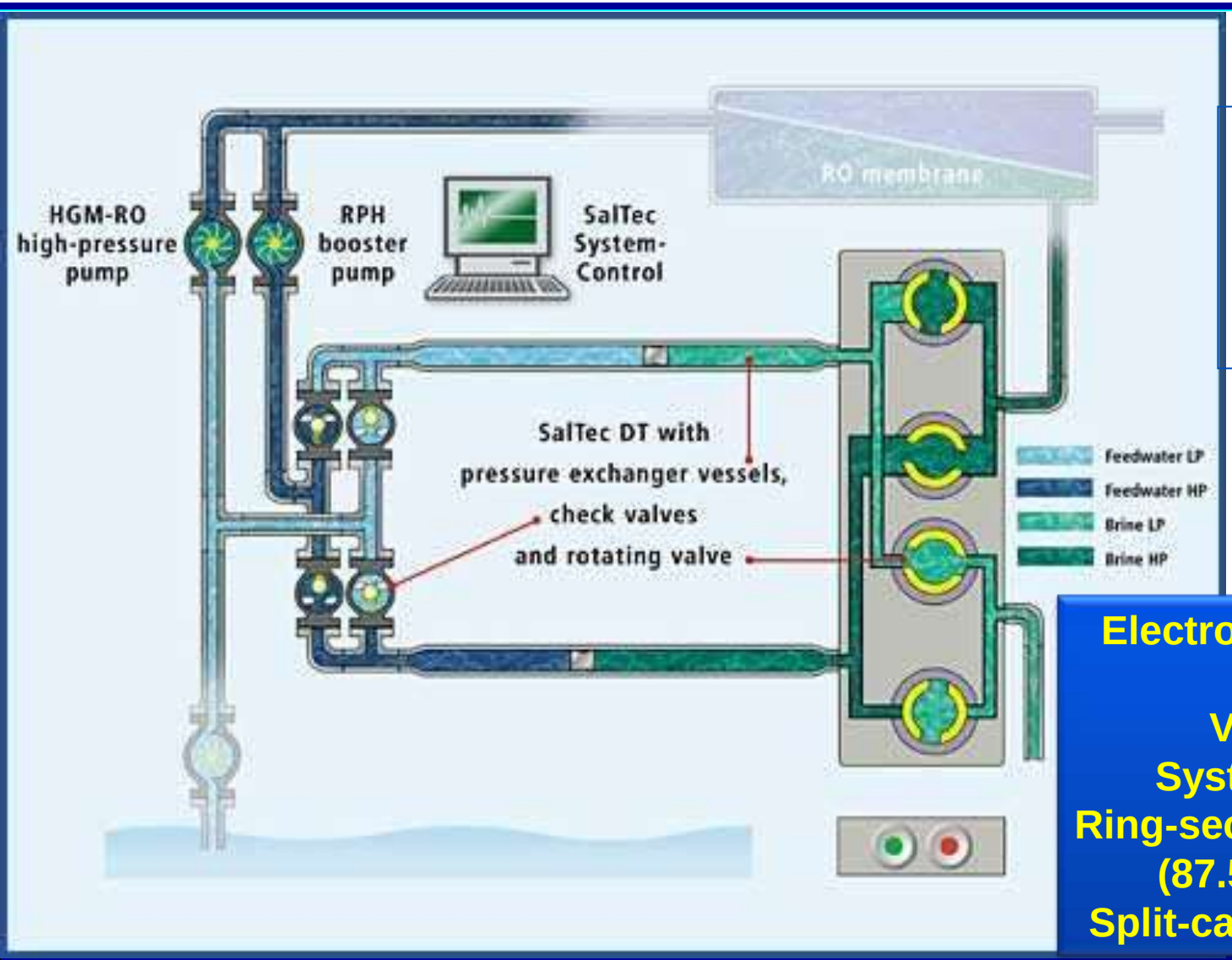
DWEER – Recent Large Projects

- **Gold Coast, Australia – 33 MGD;**
- **Sydney, Australia – 66 MGD/132 MGD;**
- **Aguilas, Spain – 48MGD.**

Calder AG (Flowserve) – ROVA 300

- **Can Handle 1.9 MGD of Brine Flow (Three Times Bigger than Existing Units);**
- **Duplex Stainless Steel;**
- **New Seal Design Reduces Brine Mixing < 1.5 %.**
- **Currently Tested in Oman and Cayman Islands.**

KSB SalTec DT Pressure Exchanger



1 MGD Units

Installed in Plants In Malta, Murcia, (Spain), and Oman.

Electronically Controlled Rotating Valves Adjust System Operations Ring-section HP RO Pumps (87.5 % Efficient) & Split-case Booster Pumps

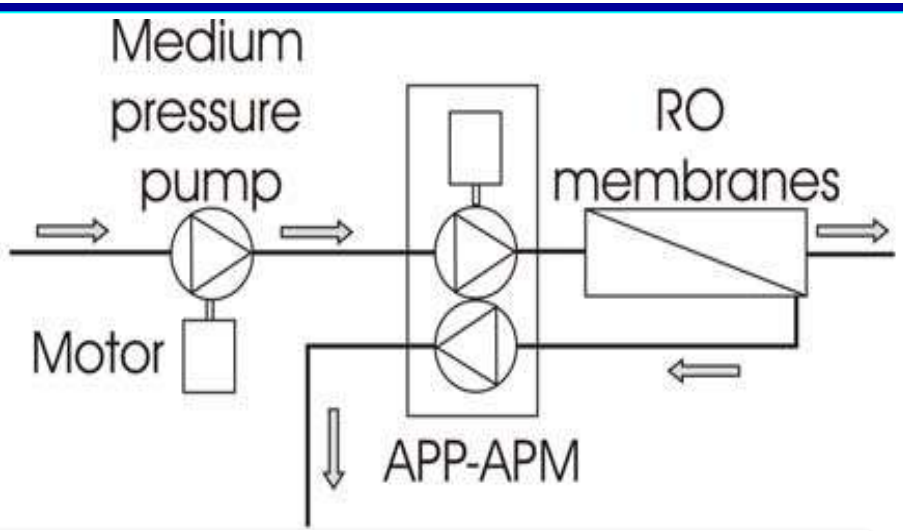
Two SalTec 250 Units Operating in 12 MGD Pembroke SWRO Plant (Malta) since July 2008

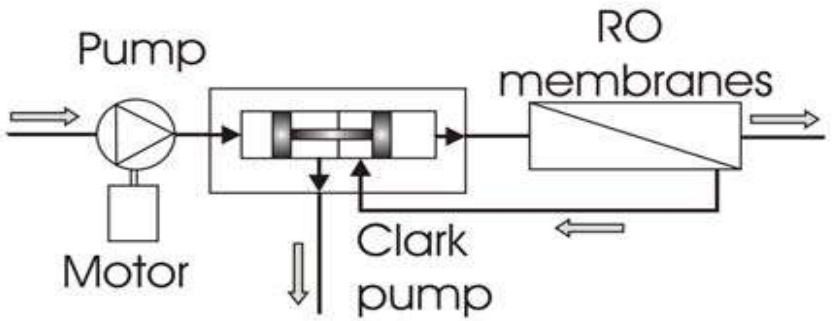
Reducing Power Use In Small Plants
A Hair Rising Challenge?

Small Systems Still Use A Lot of Energy

26 kWh/kgal
0.1 MGD
Vs.
11.3 kWh/kgal
For 50 MGD Plant

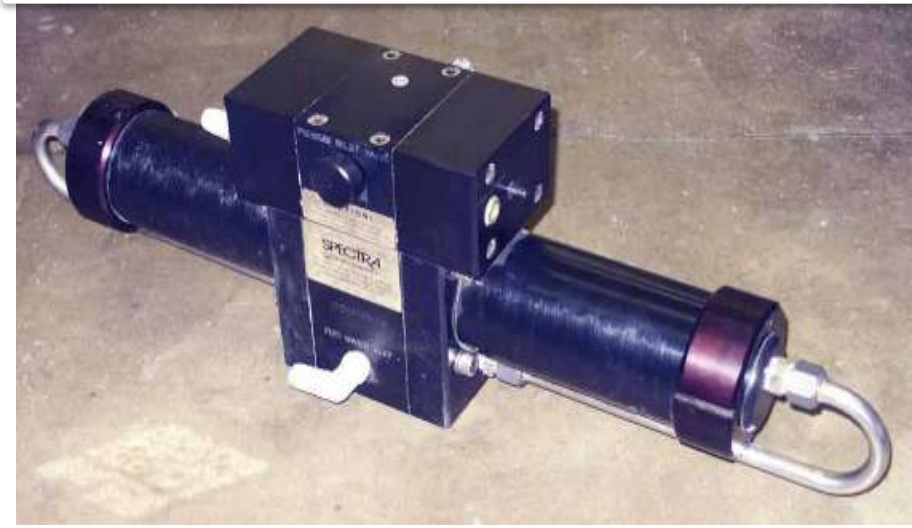
Improving Energy Recovery – Small SWRO Plants





Danfos Axial Piston Pump-Axial Piston Motor

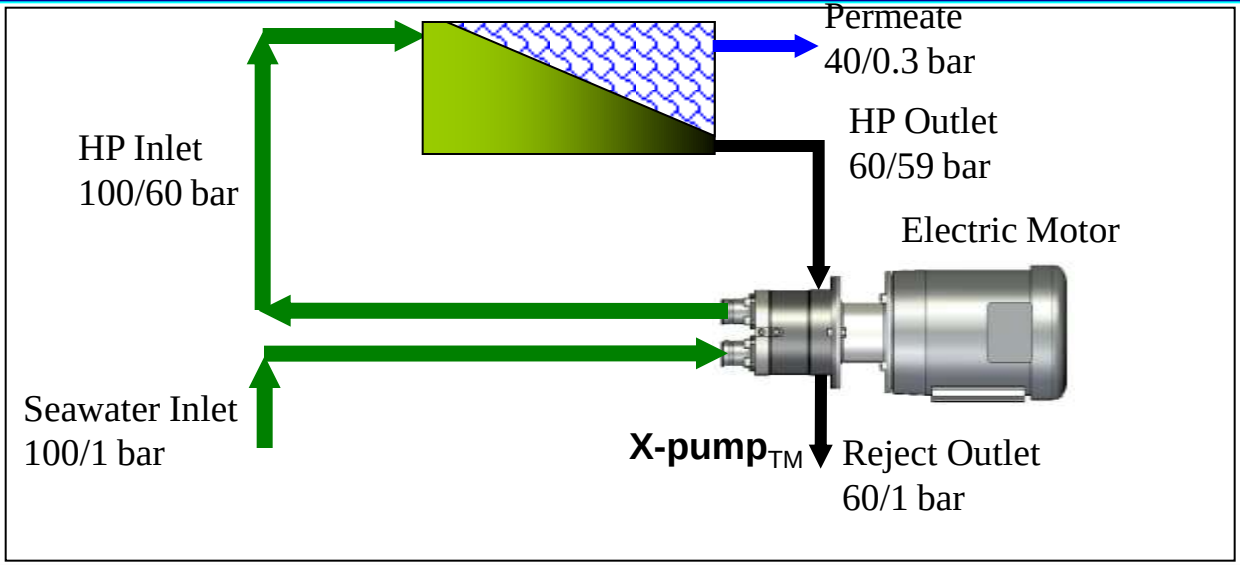
Clark Pump



Pearson Pump – Combined Pumping & Energy Recovery

- **Pearson Pump (Spectra Watermakers) – Introduced in March 2009**
  - **Recovery Ratios – 20, 30 and 50 %;**
  - **Speed 600 to 1,200 rpm**
  - **Clark Pump + Energy Recovery Amplifier (up to 3,000 gpd);**
  - **Energy Recovery – 80 % ;**
  - **Seawater Energy Use - 10 kWh/kgal;**
- **Next Generation – 12,000 to 30,000 gpd Units**

Axial Piston-Pressure Exchanger X-Pump System Ocean Pacific Technologies



X-pump Pumps 100 % of the RO Feed/ If exchanger piston are selected @ 60 %, then RO will be fixed at 40 % Recovery

- ~56% energy savings ~9.1 kWh/kgal (100 gpm)

  ~67% energy savings ~8.7 kWh/kgal (460 gpm)
- Fixed recovery – not influenced by pressure rise, salinity or temp.
- Low Complexity (water used for lubrication) – 90 % Pump Efficiency.

Summary and Conclusions

- **Key Trend - Going Bigger!**
  - **Bigger Pumps;**
  - **Bigger Pressure Exchangers;**
  - **Bigger Turbochargers.**
- **Large Pumps Allow Pushing the Envelope of Efficiency to ~ 90 %;**
- **Horizontally Split Case Multistage HPRO Pumps Dominate!**
- **Radially Split Case Pumps Have Made a Successful Debut!**
- **Pressure Exchangers Facilitate the Use of Large Pumps and Pressure Center/Three-Center Designs.**
- **Small SWRO Systems Are Nearing Energy Efficiency of Large Plants.**

Questions ?

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