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INSTALLATION, OPERATION AND MAINTENANCE MANUAL CARRIACOU

Reverse Osmosis Water Treatment System
SW-13 m^3/hr

Xylem Job #: G003489

Contents

List of Appendices

1 SCOPE

The system provided for Carriacou is a containerized unit consisting of Multi-Media filtration (MMF) for pretreatment, chemical injection systems, RO train, and chemical feed systems for post-treatment. The unit will produce 13 m^3/hr or 312 m^3/day of water with TDS < 500ppm. The RO unit is designed to operate at 43% recovery and uses pressure exchanger (PX) as energy recovery device. The major equipment provided in this system is:

1. Feedwater Pump: This pump provides the seawater feed to the plant. This is close-coupled pump rated at 38.6 m^3/hr @ 3.4 bar (170 gpm/50psi). The pump's material of construction is Nickel-Aluminum-Bronze material and equipped with 10HP motor de-rated to operate @ 400VAC/3ϕ/50Hz.
2. Multi-Media Filters, FRP construction, 48" OD, equipped with 5-way manual valve, Qty 2
3. RO HP Pump: This is an axial piston pump (positive displacement) unit capable of providing up to 13.4 m^3/hr @ 55 bar (59 gpm/800psi) The pump's material of construction is super duplex Stainless Steel (2SAF 2507) and is equipped with 40HP 1000RPM inverter duty motor designed to operate at 400VAC/3ϕ/50Hz (de-rated for 50Hz).
4. PX unit: The PX unit provided is PX-90S manufactured by Energy Recovery, Inc. known as ERI.
5. PX Booster Pump: The booster pump provided is multistage horizontal pump provided by the same manufacturer above. This pump is rated at 17 m^3/hr @ 2.4 bar (75gpm/35psi) and equipped with 10HP motor de-rated to operate @ 400VAC/3ϕ/50Hz.
6. CIP/Flushing Pump: The booster pump provided is 316LSS multistage vertical pump. This pump is rated at 27 m^3/hr @ 4 bar (120gpm/58psi) and equipped with 7½HP 1500RPM motor (4-Poles) de-rated to operate @ 400VAC/3ϕ/50Hz.
7. RO pressure housings: A total of (3) vessels are provided for this plant. Each vessel has capacity for 6 membranes. The vessels are rated at 1000psi or 69 bar.
8. RO Membranes: A total of (21) seawater membranes is provided.
9. Cartridge Filtration: Set of (2) cartridge housings with 5-micron cartridges are provided to protect the RO HP Pump downstream & the RO membranes.
10. Chemical Metering Pumps: Solenoid/Diaphragm, PVC liquid end/TFE Diaphragm/Ceramic ball valves, Manual Stroke/Manual Frequency, rated at 0.25 GPH/6 GPD/0.9 LPH, ¼" Tubing connections

1. Valves: The main valves provided in this system are:
   a. Feed isolation valve on the RO: This is ON/OFF valve equipped with motorized actuator operating at 24VDC.
   b. PX bypass valve: This is ON/OFF valve equipped with motorized actuator operating at 24VDC.
   c. Flush tank fill valve: This is ON/OFF valve equipped with motorized actuator operating at 24VDC.

   d. All other valves are typical isolation valves for various units and check valves at the discharge of each pump
2. Instrumentation to consist of the following:
   a. Two (2) paddle wheel sensors to monitor the flow on permeate, & reject lines (LP Lines). Paddle wheel flow sensors are wired directly to the PLC. All flow readings will be monitored thru HMI.
   b. One ultrasonic
   c. Two (2) conductivity sensors to measure feedwater & permeate conductivity
   d. One conductivity instrument to display feedwater & permeate conductivity or permeate conductivity & % rejection
3. Control Panel: The control panel consists of HMI (operator interface), PLC, VFDs for the RO HP Pump and PX booster pumps.
   a. The HMI is 3.8” color screen equipped with Ethernet port

b. The PLC is Allen Bradley’s Micrologix series. The PLC has (20) normal 24VDC Input, (4) fast 24VDC Input, and (16) Relay Output.

Here is the list of major components provided for this system. The internet link provided is for datasheets only.

Component	Manufacturer	Model or Part No.	Link to Datasheet/O&M on the Internet
RO Membranes	Hydranautics	SWC6 Max	
RO Cartridge Filter Housing, Qty 2	FSI	XL234	http://www.fsifilters.com/filter-vessels/plastic-filter-housings/xl234-modular-filter.html
Cartridges, 5-micron, Qty 14	2½" OD x 30" L		
RO Pressure Vessels, 1000psi	Protec	8-1000-SP	
RO HP Pump	Danfoss	APP 16	http://ro-solutions.danfoss.com/media/1124/521b1183_data-sheet-app-16-22_uk.pdf
PX Unit	ERI	PX-90S	
PX Booster Pump	ERI	HP-1253	
Feedwater Pump	Ampco	RCH2 3x3-7	
CIP/Flushing Pump	G&L	33SV20NH2_20-M01	
Metering Pumps	Pulsafeeder		http://pulsatron.salesmrc.com/pdfs/pulsatron_series_a_plus_tech_sheet.pdf
Pressure gauges	Refer to P&ID	SPAN	
Pressure Transmitters	KPSI	T-342-101500	
Pressure Switch, Low-pressure switch on the suction of the RO HP Pump	Barksdale	PH90	
Pressure Switch, High-pressure switch on the discharge of the RO HP pump	Neo-Dyn	132P-1500	http://www.neodyn.com/download/pdf/industrial/132P.pdf
Flow Sensors – LP lines	GF/Signet	2536-PO	

Component	Manufacturer	Model or Part No.	Link to Datasheet/O&M on the Internet
Flow Sensors – HP lines	Blue-White		
Conductivity Sensor – Permeate, 0.1 cm constant, 1 - 1000µS/cm	GF/Signet	3-2820	http://www.gfps.com/content/gfps/signet/en_US/sensors/conduct/sensors/2819.html
Conductivity Sensor – Feed, 10 cm constant, 100-200,000µS/cm	GF/Signet	3-2822-1	SAME AS ABOVE
Conductivity Monitor	GF/Signet	3-8860	http://www.gfps.com/content/gfps/signet/en_US/sensors/conduct/instruments/8860.html
PLC	Allen Bradley Micrologix 1200	1762-L40BWAR	http://literature.rockwellautomation.com/idc/groups/literature/documents/in/1762-in006_-en-p.pdf
HMI	Magelis	GTO 1310	http://www2.schneider-electric.com/documents/product-services/en/product-launch/hmi/magelis-gto-catalogue.pdf
VFD, 30KW	Square D	ATV61 HD30N4	
VFD, 7.5KW	“	ATV61 HU75N4	
LP Process Piping (LP = Low-Pressure)	PVC SCH 80	N/A	
RO HP Process Piping (HP = High-Pressure)	Zeron 100 SCH10S	N/A	http://content.rolledalloys.com/technical-resources/datasheets/ZERON-100_DS_US_EN.pdf

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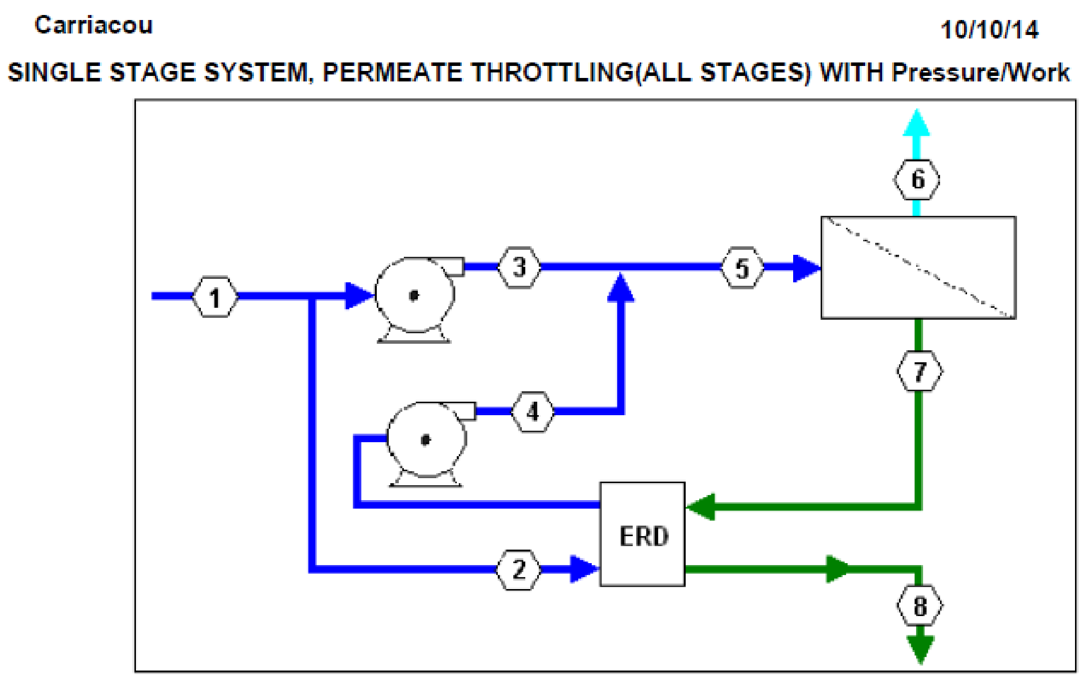
1.1 Design Parameters

The RO train is designed for 43% recovery at 25 ºC with water TDS at 37,521 ppm. The design is based on Seawater from Well source with SDI < 5 using 6-membranes in each pressure vessel for better performance at high TDS, 440 ft² surface area per membrane, flux at 10.8 GFD. The membranes used are TFC (Thin Film Composite) low-pressure membranes, Hydranautics SWC6 MAX. Summary of RO Projections show the pressure profile from start-up (0-Year) to 3-Yrs old membranes as followed:

Table 1: Pressure Profile of the RO from 0 to 3-Years

Year	Pressure (bar)	Pressure (psi)	Permeate Water TDS	Permeate Water pH
Startup	53.0		275.5	6.66
1 Year	53.4		293.5	6.68
2 Years	53.8		311.5	6.71
3 Years	54.3		329.4	6.73

Please refer to RO Projection for 3-years old membranes and PX projection in Appendix A.



		1	2	3	4	5	6	7	8
Flow	m3/hr	30.2	17.0	13.2	17.0	30.2	13.0	17.2	17.2
Pressure	bar	0.0	0.0	54.3	54.3	54.3	1.0	52.9	0.0
TDS (ppm)		36162.0	36161.9	36161.9	37885.8	37130.8	329.4	64892.0	63185.4

Figure 1: Flow Path within the RO (3-Years old membranes)

1.2 List of Consumables

Item	Qty Used	Specifications	Replacement Frequency
Membranes	18	Refer to datasheet on the internet	5 - 7 Years
5-Micron Cartridges	14	30" long x 2½" OD, Spun polypropylene - **The highest Grade possible**	Every 4 Weeks min.
Feedwater Pump Mechanical Seal	1		Every year
RO HP Pump Mechanical seal	1		Every year
PX Booster Pump Mechanical Seal	1		Every year
CIP/Flushing Pump Mechanical Seal	1		Every 3-years
Antiscalant	(note 1)	0.85 LPD based on 100% stock solution	Continuous
Caustic			“
Sodium Hypochlorite			“

Notes:

1. The anticipated antiscalant consumption based on 64 gpm feedwater and 3 ppm dosage rate is 1 kg/day (2.3 lbs/day). This is equivalent to 0.9 LPD or 37.9 ml/hr (0.24 GPD). Please note that 1 Liters/day is equal to 44.4 ml/hr, LPD = Liters per Day, GPD = Gallons per Day. Because the dosing rate is very small, it is highly recommended to dilute the antiscalant from 100% down to < 10% in order to be within the high range of the flow of metering pump. For more information on how to calculate and set the metering pump, refer to installation section.

1.3 Utilities Required

Feed (Seawater) Flowrate .... 30.25 m³/hr or 133 gpm

Power Supply Required: .... 200 Amps, 400VAC/3ϕ/50Hz

Drain for reject water (brine) .... 17.3 m³/hr or 76 gpm

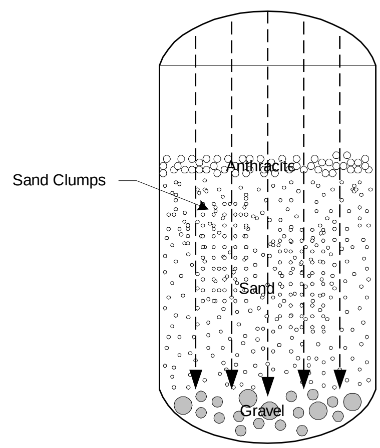
Chemicals: .... Antiscalant, Sodium Hypochlorite & Caustic

2 FLOWPATH

2.1 Flowpath thru Pre-treatment

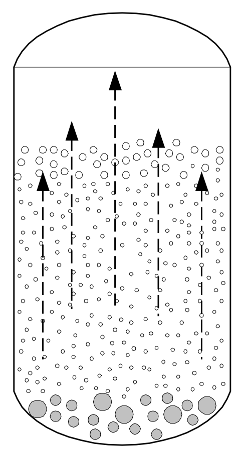
Water is pumped by the feedwater pump supplied by Xylem to two multi-media filters operating in parallel.

The duplex dual media filter consists each contains two layers of media & support media (anthracite + 45-55mm Sand + Gravel support). Seawater enters the dual media filters where particulate is removed. Typically, dual media filters remove particles 20 µm (microns) in size or larger from the feed water. The media layers are arranged with the largest, least dense granules on top and the smallest, most dense media on the bottom. From top to bottom the two active filtration layers consist of a top layer of anthracite, and a second layer of sand. The last layer is simply a gravel support.



Filter in Service

During normal operation, water flows from top to bottom through each dual media filter. As water moves downward through the bed, particulate is left behind amongst the media granules. As dirt accumulates on top and between the sand particles, the sand is clumped together, in other words, dirt binds the media together. As dirt accumulates the pressure drop increases and the dual media filter must be backwashed to remove trapped particles. In this project, we provided air blower to air scour the filter prior to backwash.


Filter in Backwash

During backwashing, the water flow is reversed. Water is forced up through the media layers, flowing from bottom to top. This causes the media layers to expand upwards, allowing particles to be swept away to drain. Because of their differing specific gravity, the layers will re-settle in their original configuration.

The feedwater pump will be used to backwash the filters using the feedwater (unfiltered seawater).

After backwashing, a down-flow fast rinse phase compacts the media layers. During fast rinse, water flows from top to bottom as in service with the rinse valve open. The fast rinse purpose is the compact the bed and to re-establish the original bed level. In this mode which lasts 2 – 4 minutes, all water is diverted to drain (rinse valve open).

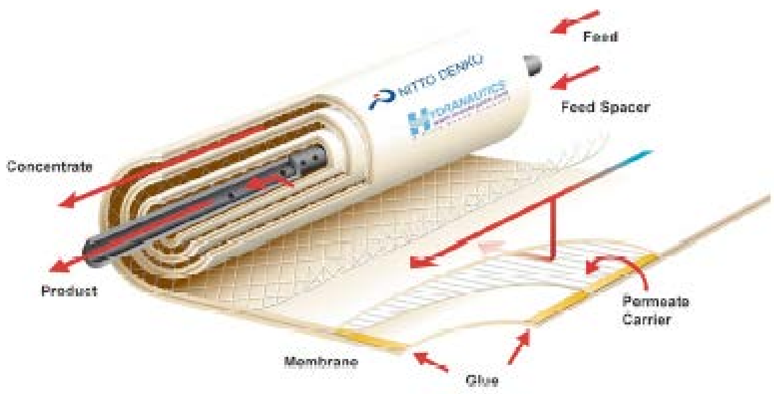
The RO feedwater is injected with antiscalant to minimize scaling potential within the membranes, especially, the last membranes in the pressure housing where most of the inorganic scaling occurs.

The filtered water travels to a set of two Cartridge Filter Housings operating in parallel. Each housing is equipped with (7) sets of 5-microns cartridges.

Within the cartridge filter housing, water enters the cartridge from the outside to the inside of the core of the cartridge. Within the core of the cartridge, filtered water is collected and discharged to the outlet header. Solids greater than 5 microns in size will be trapped on the outside. With time, more solids will be trapped and the differential pressure increases within the housing. Pressure gauges before and after the cartridge filter housing are provided to visually inspect the differential pressure (ΔP), and pressure switch with indicator is provided to alarm operator in the control room of excessive ΔP. When ΔP exceeds 0.75 to 1 bar or 10-15 psi, the cartridges must be replaced. It is a good practice however to optimize the plant so that cartridges are replaced on regular interval without relying on visual inspection of differential pressure or relying on differential pressure switch or transmitter.

2.2 Flowpath thru RO Membranes

After being injected with antiscalant and filtered by the multi-media filters, the RO feedwater enters the two pressure vessels connected in parallel where RO membranes are connected in series within each vessel. The feed stream splits into major streams: Permeate and Concentrate or Reject.



The flowpath within RO membrane is difficult to explain. But in general, RO membrane is a flat sheet wrapped or rolled around a perforated central permeate tube (PVC pipe). Feed flows thru the feed spacer, made of vexar-type netting with a thickness between 28 and 31 thousandths of an inch, in a spiral path which is hard to visualize or describe in graphics. The space between the channels is 0.7 mm thick, and if there is a high level of suspended solids in the feed water, the brine spacer can become plugged.
Within the membrane, pressurized water permeates from the brine spacer thru the vexar elements, thru the membranes, into the permeate carrier which carries the water to the permeate tube where it gets collected. The permeate water travels from the inside of the permeate tube in the first membrane, thru the membrane interconnectors, and into the second membrane. The low-pressure permeate from all vessels are collected in one manifold where it is routed to a storage tank.
The reject keeps flowing between the feed spacers from one membrane to the next one where it exits the last element or membrane to the reject piping.
So within the RO, the feed stream splits into streams after going thru the membranes: the permeate and the reject. Permeate water or the good water accounts to roughly 40% of the feedwater in the 1st pass and 80% in the 2nd pass.

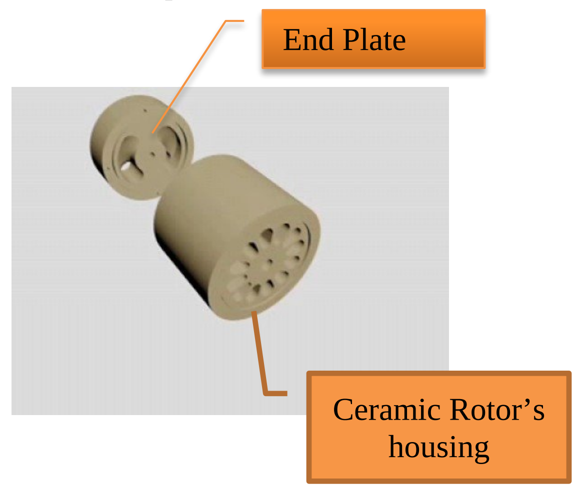
Incidentally, RO membrane's design is called "spiral wound" which refers to the flow path of water within the membranes.

2.3 Flowpath thru Pressure Exchanger

The flowpath thru pressure exchanger is complicated. It is best to visit the company's website at www.energyrecovery.com or go to google and check this old video posted by the manufacturer which is now posted on YouTube at http://www.youtube.com/watch?v=udffed4Pq3g.

A PX system consists of the following:

1. Pressure Exchanger(s) which consists of the following:
   a. Pressure Housing same as RO pressure housing
   b. Ceramic Rotor – This is the heart of the PX system. The rotor allows the HP (High-Pressure) brine stream to push the LP (Low-Pressure) feed stream directly. The rotor rotates at approximately 1200 RPM when RO HP pump starts pressurizing the system.
   c. Ceramic Rotor's housing
   d. End plates
2. PX Circulation Pump: This pump is always driven by VFD and its function is to re-pressurize the HP (High-Pressure) feed because the HP brine is lower in pressure than the RO HP pump pressure stream C.



LP feed from Seawater LP pumps or from pretreatment splits into two streams: One stream flows into the RO HP pump, and one flows directly into the PX unit. Both of the LP streams are located on one side of the PX unit. The HP reject/brine from the RO flows into the PX unit HP brine IN connection to pressurize the LP feed entering the PX unit. This stream is pressurized by the PX circulation/booster pump and combined with the stream pressurized by the RO HP pump. These two streams becomes essentially the Seawater Feed to the RO unit. As the HP brine transfers all of the pressure to the LP feed to the PX unit, it exits from the LP brine OUT connection from the PX unit at very low-pressure (1 bar minimum).

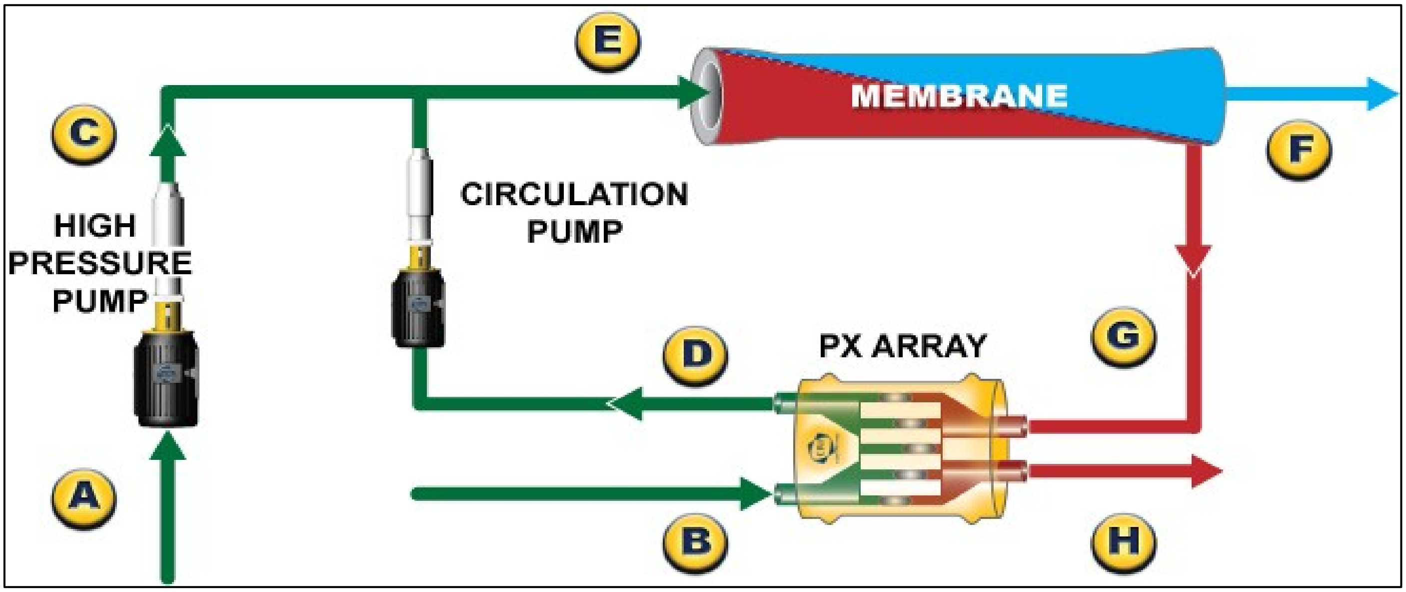


Figure 1: Schematic Diagram of a PX Device

In Figure 1 shows the various paths of all streams. The purpose of the PX system is to pressurize portion of the seawater feed which is equal to reject or brine flow by the PX unit, and to pressurize the remainder of the feed which is equal to permeate flow by the RO HP Pump. We will use LP & HP for all streams as abbreviations for Low-Pressure & High-Pressure.

Stream A is the LP Feed stream which splits into streams: Stream B flowing into the PX LP feed side, and stream C which flows into the RO HP pump and is pressurized by the RO HP pump. Stream C is combined with stream E as it enters the RO housings.

Stream C is the portion of the LP feed which is pressurized by the RO HP pump to the reverse osmosis required according to RO projection. A check valve at the discharge of the RO HP pump will isolate that stream from stream E.

Stream G is the HP brine which is the main source of pressure for the LP feed stream (Stream B). Pressure transfers from the high-pressure concentrate stream [G] to a feed stream [B]. The rotor spins freely, driven by the flow at a rotation rate proportional to the flow rate and lubricated by high-pressure process water. Unlimited capacity is achieved by arraying multiple PX devices in parallel.

Stream D is the HP feed stream which is pressurized by Stream G. Since the reject or brine stream's pressure (Stream G) is usually 1 to 2 bars less than Stream C, the circulation pump is provided to add that pressure as it mixes with Stream C. The flow from the circulation pump is combined with Stream A to become Stream E.

Stream H is the LP brine exiting the PX system. The pressure of this stream should be no less than 1 bar (14.5 psi). This is the same stream G which has lost its pressure to Stream B and lost a little bit of water for lubrication of the rotor.

In a reverse osmosis system equipped with PX Pressure Exchanger® energy recovery devices, the membrane reject is directed to the membrane feed as illustrated in Figure 1. A rotor, moving between the high-pressure and low low-pressure streams, removes the reject concentrate and replaces it with feed water. .

The PX devices and the check valve at the discharge of the high-pressure pump seal the high-pressure portion of the RO process. During RO-process operation, water is introduced to the high-pressure loop [D-E-G] by the high-pressure pump as stream C. Almost all of this water exits as permeate and the rest flows through narrow gaps that surround the PX device rotor, creating a nearly frictionless hydrodynamic bearing. Lubrication flow is typically about 0.5% of the total flow from the high-pressure pump and is measurable as the difference between the high-pressure pump flow rate [C] and the permeate flow rate [F].

The flow delivered by the high-pressure pump and the resistance to permeate and lubrication flows provided by the membrane elements and the PX devices, respectively, pressurize the high-pressure loop. Although water is also introduced to the high-pressure loop by the PX devices at process location D, an equal flow rate of water is removed by the PX devices at process location G.

The PX system is divided into two loops: High-Pressure (HP) and Low-Pressure (LP). The HP loop and the LP loop are completely independent. The flow in the HP loop is almost constant and the only way to increase recovery is to increase the flowrate of the RO HP Pump.

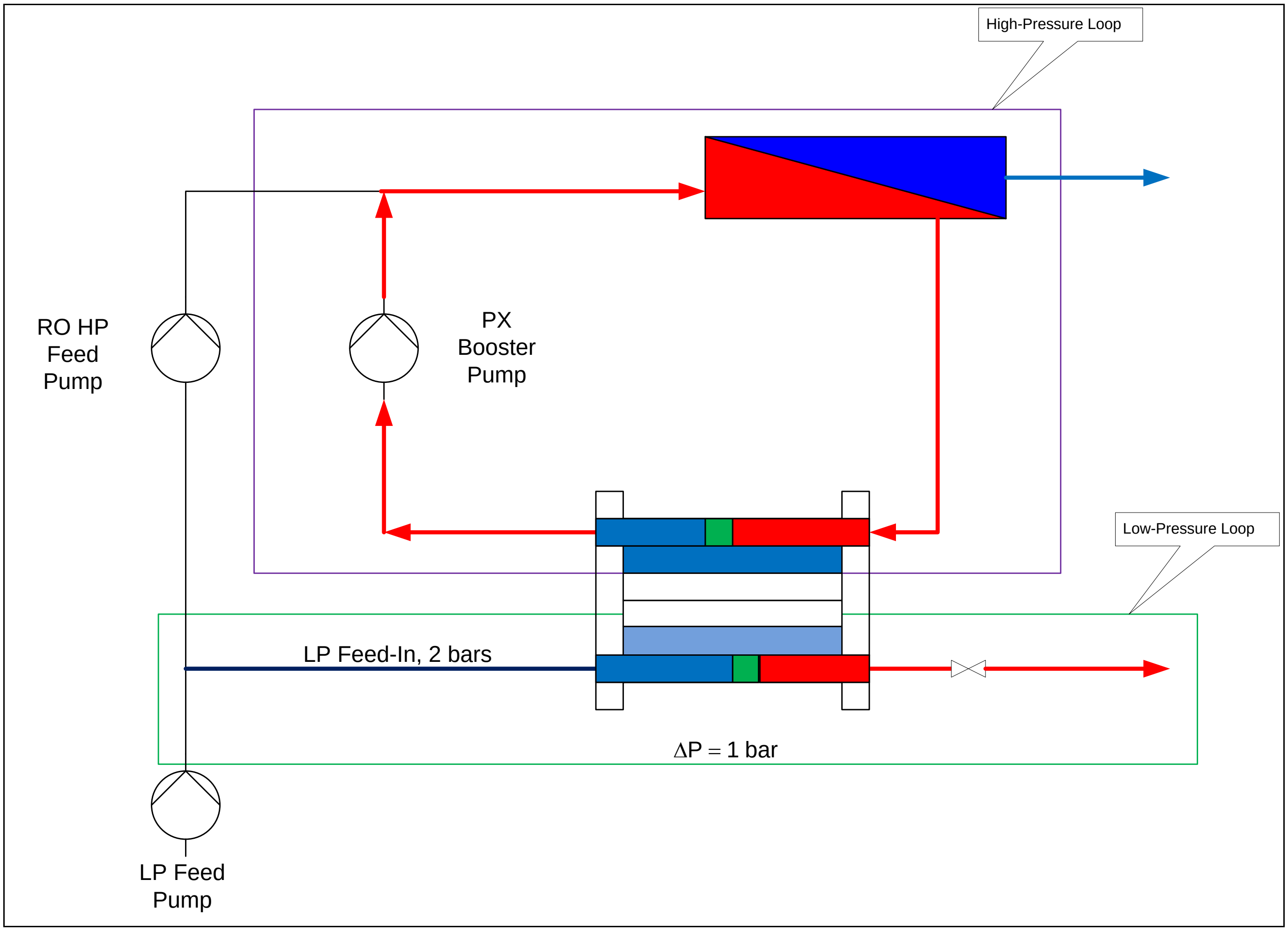


Figure 2: ERI Operation

The manufacturer, ERI, prefers to see a pressure not exceeding 2-bar for the low feed-in line (Stream B). According to ERI, the expected pressure drop is 1 bar across the unit. The low-pressure-Brine-Out line (Stream H) should be equipped with a valve to keep a backpressure in order to ensure constant lubrication inside the rotor - this is equivalent to maintain constant NPSH in case of pump.

1.1.1 RO Process Startup and Shutdown

A reverse-osmosis process equipped with PX technology is started up with the following sequence:

1. Start the feed water supply pump
2. Start the circulation or booster pump
3. Thoroughly vent air from the process
4. Start the high-pressure pump

The RO system is not pressurized before the high-pressure pump is started.

1.1.2 RO Process Shutdown

A normal shutdown sequence is as follows:

1. Shutdown the high-pressure pump
2. Wait until the concentrate has been displaced from the SWRO system by the circulation pump and the PX devices
3. Shutdown the circulation pump
4. Shutdown the feed water supply pump

The system remains pressurized at the osmotic pressure of the feed water by osmotic or "suck-back" flow. After the high-pressure and circulation pumps stop, system pressure decreases very slowly as lubrication water is pushed through the PX device lubrication channels and into the low- pressure piping. Osmotic pressure decreases as suck-back permeate accumulates in the membranes. If more rapid depressurization is necessary, a vent valve in the high-pressure loop must be opened.

1.1.3 Flushing

RO membranes require occasional flushing to limit biological fouling. Biological fouling can increase RO process energy consumption and cause malfunctions. There are two types of flush: Feed Water Flush (Pre-Flush) and Fresh Water or Permeate Flush (Post-Flush). Regardless of the flush water used, all parts of the PX device must be flushed, i.e. low-pressure flow channels, high- pressure flow channels, and lubrication channels. Refer to ERI's Installation, Operation and Maintenance Manuals for specific information about flushing requirements.

Step (2) of a normal shutdown sequence is a Feed Water Flush. Both permeate and concentrate production have ceased and high-pressure and low-pressure bulk flows through the PX devices continue. The flow path of the Feed Water Flush, with reference to Figure 1, is B-D-E-G-H driven by the feed water pump and the circulation pump. A Feed Water Flush is typically continued until conductivity measurements at process locations G and H are satisfactory.

A Permeate Flush is performed on a partially- or fully-depressurized system. This is accomplished by introducing permeate simultaneously to the PX device low-pressure inlet [B] and either to the high-pressure pump inlet [A] or through some other injection point such as a CIP connection. Permeate may be produced during this flushing process. If so, it may be necessary to block permeate flow to divert lubrication flow through the PX devices.

1.1.4 PX Rotor Lubrication

Both process flow and lubrication flow are required for the PX rotor to spin. The process flows include the feed flow from the supply system introduced to the PX devices at process location B in Figure 1 and the concentrate flow driven by the circulation pump. Lubrication flow is normally provided by the high-pressure pump as described above. The lubrication flow rate is typically less than 1% of the high-pressure pump flow rate or less than 0.5m³/hr (2.2 gpm) per PX device.

Without lubrication flow, the PX device rotors may stop rotating. If this occurs, the concentrate-feed water exchange will cease. Flush water introduced at process location B will exit at process location H without flowing through the membrane array. With insufficient lubrication flow, rotor rotation can result in damage to the PX device's ceramic components. A grinding sound may be heard as the ceramic components rub together without lubrication.

If the high-pressure pump is not on, such as during flushing, the lubrication flow necessary to keep the PX rotors spinning can be provided by osmotic (suck-back) flow through the membranes. However, if the RO process is fully depressurized, the lubrication flow necessary to keep the rotors spinning must be either pushed through the high-pressure pump by the supply pump or injected through some other point in the high-pressure loop such as a clean-in-place (CIP) inlet. If the flush water has very low salinity, the lubrication flow may exit the process through the membranes under low trans-membrane pressure. It may be necessary to block permeate flow to divert lubrication flow through the PX devices.

The following conditions apply:

1. Allowable flow ranges for individual PX Units are listed in Table 1. PX units are not designed to operate outside of these ranges.
2. 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.
3. Piping connections to PX units must be designed to minimize stress on the fittings and vessel.
4. The PX unit must be vessel bearing plates (end caps) incorporate interlocking restraining devices which must be kept dry and free of corrosion. Deterioration of these devices could lead to catastrophic mechanical failure of the PX side.
5. The PX unit must not be exposed to temperatures less than 1ºC (33ºF) or greater than 45ºC (113ºF).
6. Under no circumstances shall be brine inlet pressure (HP IN) exceed 82.7 barg (1200psig).
7. The Seawater feed inlet shall not exceed 10.3 barg (150psig). The minimum discharge pressure from the PX unit shall be 1 barg (15psig).
8. 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 hydrostatic test a PX device.
9. Some chemical additives are known to be the cause of operational failure of PX unit(s). These chemicals include, but are not limited to polyacrylates, occasionally used for scaling prevention. These chemicals can cause PX device failure by forming a sticky substance which physically jams the PX unit(s).
10. 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.

1.1.5 PX Units

Table 2: PX Units Flow Ratings

Model	Flowrate (m^3/hr)	Flowrate (gpm)
PX-30S	4.5-6.8	20-30
PX-45S	6.8-10.2	30-45
PX-70S	9.1-15.9	40-70
PX-90SR	13.6-20.4	60-90
PX-140S	20.4-31.8	90-140
PX-180	32.0-41.0	140-180
PX-220	41.0-50.0	180-220
PX-260	50.0-59.0	220-260
PX-300		

In this plant, a single unit PX-90SR is provided as described in section 1.0.

For small systems, Xylem uses ERI's circulation/booster multistage horizontal pumps. All these pumps are equipped with inverter duty motors to be driven by VFD.

Model	Flowrate (m^3/hr)	Flowrate (gpm)	TEFC Motor (60Hz)	TEFC Motor (50Hz)
HP-8503	11.4-15.9	50-70	5 HP	5
HP-8504	15.9-22.7	70-100	7½ HP	7½
HP-1253	22.7-36.4	100-160	10 HP	10
HP-1254	36.4-45.4	160-200	15 HP	15
HP-2402	29.5-52.3	130-230	15 HP	15
HP-2403	52.3-68.2	230-300	20 HP	20

In this plant, a HP-1253 is provided as described in section 1.0.

2.4 Flowpath thru Post-Treatment

The post-treatment provided for this plant consists of only caustic injection & sodium hypochlorite. Caustic must be injected to increase pH up to 7.5.

2 PROCESS CONTROL DESCRIPTION

When there is call for water, the RO starts and when there is no demand for water, the RO stops. The RO start & stop is controlled by the level in the permeate water tank. The RO will operate between two levels which will be set during start-up of the system.

Before the SWRO start producing permeate water, it must fill the flushing tank first. Whenever the PLC detects level below high-level setting, it will open inlet valve to the flushing tank until water reaches the high-level alarm's setting.

Flushing time will be set during start-up. The first time the unit is flushed, it will be monitored to check how long it will take for the conductivity of the reject to reach the same as the conductivity of the incoming flushing water. Volume of flushing water requirement is dependent on the size of the RO or the volume required filling all components within the unit (piping, pressure vessels, pumps, etc…).

The SWRO HP Pump is controlled by the PLC to maintain constant permeate flowrate. The PLC will use a PID control to change the motor speed of the SWRO HP pump based on Permeate Flowrate. In this plant, the RO HP Pump is driven by VFD. Changes in flowrate occurs because either the temperature have changed, the feedwater quality have changed (usually seasonal), and because of fouling (with time).

The SWRO shall maintain a constant recovery at a setpoint value of 43%. The setpoint value shall be calculated in the PLC by the following equations:
$R = [P_{mf}/(P_{mf} + C_{mf})] *100$

where:
R = Recovery
$\mathbf{P_{mf}}$= Permeate measured flow rate
$\mathbf{C_{mf}}$ = Concentrate or Reject measured flow rate

The concentrate flow rate should not go below 6.4m³/hr which is the minimum flow for SWRO unit operating (14gpm or 3.18m³/hr per pressure vessel). If someone accidently closes a valve downstream of the PX unit(s), LP brine OUT, during service, the PLC will stop the RO unit immediately.

Scale inhibitor or Antiscalant metering pump will be interlocked with SWRO HP Pump. The injection will not start until the permeate flow have reached its setpoint. If there is low level alarm in the antiscalant tank, the HMI will show a warning to operators to fill the tank with antiscalant. The RO unit will not shut down the RO unit when there is no antiscalant.

If there is differential pressure alarm across the cartridge filter housing(s), the alarm must be set at 1 barg or 15 psig, and a warning will be shown on the HMI to alarm operator to schedule a time to change the cartridges. If there is no differential pressure instrument, operator must visually inspect the differential pressure and shut down the unit when the value exceeds the 1 barg or 15psig benchmark.

The plant should not rely on this instrument however. After start-up, operators should establish a time period for changing out cartridges every "x" months or weeks to prevent build-up of high ΔP. We cannot emphasis the importance of cartridges in the operation of desalination plant.

If your system is equipped with sodium bisulfite to de-chlorinate the water, the metering pump will be interlocked with the SWRO HP Pump. If there is low level alarm in the sodium bisulfite tank and the feedwater is known to be chlorinated all the time, the HMI will show an alarm that will shut down the RO train.

Flushing system is an integral part of the SWRO equipment. It is critical that SWRO will be flushed immediately after shut-down – This will be referred to as Post-Flush. The SWRO will also be flushed on Start-up – This will be referred to as Pre-Flush.

Pre-Flush (flush @ start-up) is also required but is not as critical as the Post-Flush.

All alarms will be displayed on the HMI which requires action by the operator. The operator must ACKNOWLEDGE and RESET the alarm after investigating the problem.

2.1 Modes of Operation

The PLC panel's door has the following selector switches, pushbutton, and instruments:

1. SYSTEM: HOA (HAND/OFF/AUTO)
2. Feed Pump: HOA
3. Flush Pump: HOA
4. Reset Pushbutton
5. Emergency Pushbutton
6. Conductivity Monitor
7. HMI

In HAND, the RO start-up is initiated by the plant's operator manually regardless of the level in the permeate water storage tank downstream. This is reserved to start the RO during the start-up & commissioning. RO train however will not start in any mode, HAND or AUTO, under the following conditions:

1. If there is Fault or Trip alarm from RO HP pump, Transfer pump or feedwater pump
2. If there is low-level alarm in the feedwater storage tank if there is one
3. If there is persistent low-pressure alarm due to low-pressure in the suction line of the RO HP pump

In AUTO mode, the RO train will be controlled by the rise or fall of water level in the storage tank downstream. START/STOP of the RO train is controlled specifically by the level in the permeate storage tank.

All permissible conditions must be met for the RO to start. A sample of permissible conditions is shown in Figure

Each START will be preceded by 2-5 minutes flush. The feedwater pump will push water thru the RO and the PX unit while the RO HP Pump is off. During Pre-Flush, the PX booster pump will circulate the water thru in the high pressure. Flushing is a high-volume low-pressure operation whereby the water within the membranes are flushed out of the system thru the reject line.

In OFF, the RO HP pump and transfer pumps shuts down the RO regardless. OFF is mainly to allow maintenance on the RO unit or to shut down the unit during start-up & commissioning.

CIP is only available in manual mode. CIP requires filling the CIP/Flushing tank with unchlorinated permeate water, mixing the chemicals to the right pH or close enough which must be done manually, recirculation of the solution until the right pH and temperature is achieved (warming up the solution to 35ºC if needs be if there is a heater inside the tank).

When verifying the status of ON/OFF valves in the RO, the PLC will always look for closed contact.

Valve	Tag No.	Status	Contact	
Feed isolation valve		AUTO, Closed	NC	ZSC contact is closed
PX Bypass Flush Valve		AUTO, Closed	NC	ZSC contact is closed

NC = Normally Closed; NO = Normally Open

2.2 Types of RO Shutdown

There are two types shutdown:

a) **Type I Shutdown**: This is an emergency shutdown due to process alarms which would cause significant damage to the membrane system if the process were allowed to shutdown normally.

b) **Type II Shutdown**: This is a normal shutdown initiated by the operator or caused by alarms that would not cause damage to the process if the normal shutdown steps were allowed to occur.

After any type of Shutdown, the RO is flushed immediately. The duration of the flush will be determined during commissioning.

2.2.1 List of Alarms

1. Low Pressure alarm: This alarm will protect the pump from cavitation due to low flow. The low-pressure alarm is activated by pressure switch installed on the suction line of the RO HP pump.
2. High Pressure alarm: This alarm will protect the RO pressure vessels & membranes from excessive pressure. The high-pressure alarm is activated by pressure switch installed on the discharge line of the RO HP pump.
3. Low Concentrate Flow: This is critical alarm - closing the valve accidentally on the LP Brine Out will damage the membranes.
4. High Concentrate Flow Alarm:

5. RO HP Pump Fault: Fault may be generated by failure of VFD or overload
6. PX Booster Pump Fault: same as above.
7. Feed Pump Fault: This pump is not driven by VFD. Possible fault will be overload.
8. CIP/Flushing Pump Fault: Same as above.
9. High Product Flow:
10. Pretreatment Lockout
11. High Booster Flow
12. High Conductivity Alarm: This is caused by number of factors:
    a. Changes in Seawater quality or high temperature
    b. Damages of membranes, or possibly interconnectors O-rings displacement
    c. Possible too much intermixing of HP Brine IN and LP Feed IN inside the PX unit.
13. Low level alarm in Antiscalant storage tank
14. Low level alarm in Sodium Bisulfite storage tank
15. Feed Isolation Valve Fault: This is caused by limit switches when PLC command the valve to open or close and the valve do not open or close as commanded by the PLC.
16. PX Bypass Valve Fault: Same as above.
17. Fill Tank Valve Fault: Same as above.

Alarm activation is displayed on the operator interface (HMI). To clear an alarm, correct the cause, push the RESET button on the HMI. The alarm will repeat if the condition has not been corrected. Refer to the Troubleshooting section of this manual for help in corrective maintenance diagnosis. The OEM Literature section contains more detailed RO system diagnostic information for reference.

Any alarm condition that shuts down the RO initiates a post-flush cycle to protect the membranes.

2.4.1 Sequence of Operation

The RO system takes the customer's feed water, treats the feed water and sends the permeate water to the customer's storage tank. The RO system consists of a 40HP high pressure pump that sends the water through the membranes. The water flowing through these membranes is separated into two streams, permeate or product water, and concentrate or reject water. The permeate water flows to the customer's storage tank. Part of the concentrate water flows to the reject line. The other part of the concentrate water flows though a pressure exchanger, which acts as an additional pressure booster for the feed water flowing into the membranes. The unit can be started manually by the operator or automatically based on level in the product storage tank. A 10HP feed pump is used to feed water through the pretreatment filtration and into the RO system.

A. Two modes of operation:
   1. Manual: The RO system will run when the H-O-A switch is placed in the manual position.
   2. Automatic: The RO system will run based on product tank level.

B. RO MANUAL (HAND) OPERATION START-UP:
   1. In manual mode the start of the system is not based on product tank level. Note: Running the system in manual may result in tank overflow.
   2. The PLC continues to monitor the system and will shut down the system on an alarm condition.
   3. The RO system will start by first going into preflush mode.
      a. The feed pump is started.
      b. The inlet valve will open to fill the membranes with feed water.
      c. The concentrate flush valve will open to allow the feed water to flush.
      d. The PLC will send a signal to start the antifoulant chemical pump.
      e. The ERI booster pump will start.
      f. The preflush cycle will continue for the time entered in the HMI by the operator.
      g. The concentrate flush valve will close after preflush cycle is complete.
   4. Once preflush is complete the RO unit will fill the flush tank.
      a. The PLC starts the RO pump.
      b. The PLC will send a signal to start the CL2 and NAOH pumps.
      c. The CIP/flush tank valve will open.
      d. The RO unit will fill the flush tank until it reaches the full level.
      e. Once the flush tank is full, the CIP/flush valve will close.
      f. The water in the flush tank is used to flush the RO unit with product water during the post flush cycle.
   5. After the flush tank is full, the RO station will run to fill the product storage tank.

C. RO Manual Operation Shut-down
   1. When the system is turned off, or if there is an alarm condition, the RO system will perform a postflush.
      a. The PLC stops the feed pump, RO pump and booster pump.
      b. The antifoulant chemical pump is stopped.
      c. The inlet valve will close.
      d. The RO concentrate flush valve opens.
      e. The RO flush pumps starts.
      f. The booster pump is restarted.
      g. The postflush cycle will continue for the time period entered in the HMI by the operator.
      h. The RO concentrate flush valve will close when the postflush cycle is complete.
      i. The RO flush cycle is complete.
   2. If RO system is in an alarm state, the system will require an alarm reset before the system can re-start.

D. RO Automatic Operation Start-Up

6. In automatic mode the system will start when the level in the product storage tanks falls to the low level and will stop when the level rises to the high level. Low level start and high level stop dry contact inputs are wired to the PLC. These level signal contacts are provided by the customer.
7. The RO system will start by first going into preflush mode.
    - h. The feed pump is started.
    - i. The inlet valve will open to fill the membranes with feed water.
    - j. The concentrate flush valve will open to allow the feed water to flush.
    - k. The PLC will send a signal to start the antifoulant chemical pump.
    - l. The ERI booster pump will start.
    - m. The preflush cycle will continue for the time entered in the HMI by the operator.
    - n. The concentrate flush valve will close after preflush cycle is complete.
8. Once preflush is complete the RO unit will fill the flush tank.
    - g. The PLC starts the RO pump.
    - h. The PLC will send a signal to start the CL2 and NAOH pumps.
    - i. The CIP/flush tank valve will open.
    - j. The RO unit will fill the flush tank until it reaches the full level.
    - k. Once the flush tank is full, the CIP/flush valve will close.
    - l. The water in the flush tank is used to flush the RO unit with product water during the post flush cycle.
9. After the flush tank is full, the RO station will run to fill the product storage tank.

E. RO Automatic Operation Shut-down

3. When the storage tank reaches the high level, or if there is an alarm condition, the RO system will perform a postflush.
    - a. The PLC stops the feed pump, RO pump and booster pump.
    - b. The antifoulant chemical pump is stopped.
    - c. The inlet valve will close.
    - d. The RO concentrate flush valve opens.
    - e. The RO flush pumps starts.
    - f. The booster pump is restarted.
    - g. The postflush cycle will continue for the time period entered in the HMI by the operator.
    - h. The RO concentrate flush valve will close when the postflush cycle is complete.
    - i. The RO flush cycle is complete.
4. If RO system is in an alarm state, the system will require an alarm reset before the system can re-start.

F. The RO system PLC will monitor for alarm conditions both in automatic or manual operation.

- a. The PLC will create a fault if these values are out of range, perform a postflush and shut down the RO system.
- b. The setpoints for the alarms and delay times are entered into the HMI by the operator.
  See Table 1 for list of alarms.

3 INSTALLATION INSTRUCTIONS

The Start-Up of a RO Train requires the following:

1. Sanitation of the RO pressure vessels
2. Loading 5 micron cartridges in the Cartridge Housing skid
3. Loading membranes in the RO Pressure Vessels
4. Flushing
5. Start-up
6. Initial Feed Water Tests

3.1 Sanitation/De-Sanitation

Once all mechanical piping has been installed and media is loaded in the filters, it is suggested to flush the RO Housings with chlorinated water. It is advisable to perform this sanitation process with 25-ppm chlorine in water. To ensure complete sanitation, inside of the housings must be dried and cleaned with clean cloth.

Requirement	Procedure
55-gallons Drum	Remove the heads on the 8" vessels, Refer to Codeline (Pressure Vessels) O&M.
Water	Mix the drum with water then chlorine (always add chemical to water) using a drum pump. Take a sample from the drum and verify with chlorine test kit if residual is over 25 ppm
Rag & a Plastic Pipe	Place the rag in the drum and using a heavy plastic pipe, push the rag inside the pressure vessels and make sure to cover all the areas inside the vessel
Household bleach (6% chlorine)	Repeat the produce for the other two vessels
Portable mixer	
Chlorine test kit	

After sanitization with chlorine, it is very important to remove any excess chlorinated water from the RO housings. Here is a description of a simple procedure on how to accomplish this task:

Requirement	Procedure
Bucket	Wear protective equipment – as a minimum, wear long sleeve gloves & eye goggles
Sodium Bisulfite	Prepare a solution of sodium bisulfite in a bucket
Cloth	With your hand, soak a clean cloth with this solution
Gloves & eye goggles	Wipe the inside of the RO housing and make sure you catch all corners and areas where water has no place to go (Grooves, threads, etc…)

3.2 Loading Membranes

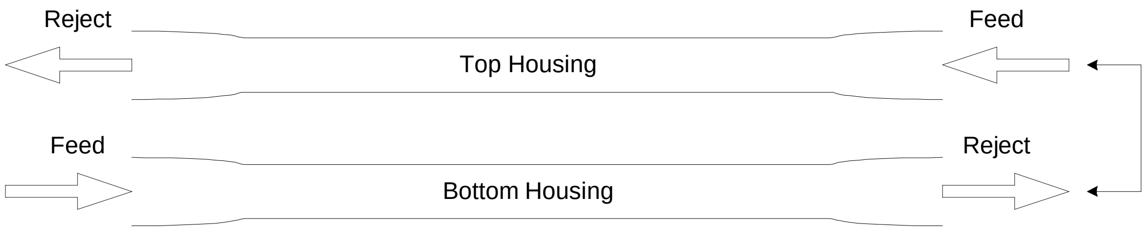
Before loading the membranes, please remember to record all membranes serial numbers in a notebook, and document the position of each membrane in each vessel as it is being loaded. Since this is small RO where there are (2) vessels, label the vessels as PV-1 & PV-2.

Here is the only thing that you need to know before loading the membranes in a specific RO housing: which is the feed end on that RO housing? (The opposite end is always reject). Once you identify the feed end, you may load the membranes.

<u>Procedure</u>

1. Identify the feed end of the RO housing.

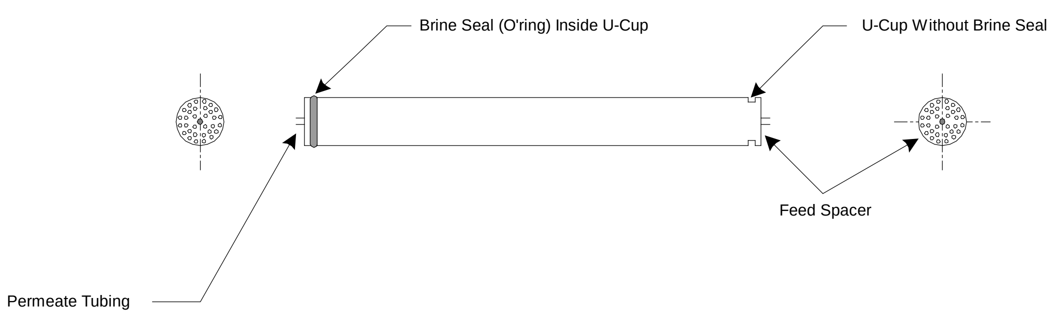
2. The configuration of this RO consists of one stage where two housings are in series. As you can see from this sketch, reject of the 1st or bottom housing becomes feed to the 2nd or top housing.



3. Remove both ends (feed side & reject side) from that housing

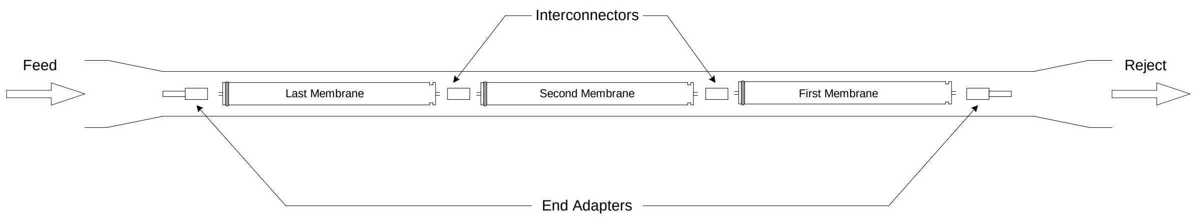
4. Remove RO membranes from the box. Each RO membrane is equipped with interconnector.

5. Identify the location of the brine seal on the RO membranes. The brine seal is an O'ring located on one end of the membrane – it is actually inserted inside the U-cup of the feed spacer. As you can see from the sketch below, the membranes are equipped with two feed spacers – one on each end.



6. Apply glycerin on the brine seal

7. Insert the membranes as shown below. Interconnectors are used to connect membrane to membrane, while the end adapters are used to connect membranes to RO housing head, which only implies to the 1st and the last membranes. Inside the interconnectors & end adapters, there are O'rings. These O'rings require lubrication. Apply again glycerin before inserting the adapters.



3.2.1 Parts Required

- (8) RO membranes, Hydranautics, SWC5
- (8) Interconnectors
- (4) End Adapters
- Glycerin as needed
- Gloves & clean cloth

3.2.2 Loading Membranes in pictures

Membrane stacks

Membranes within boxes

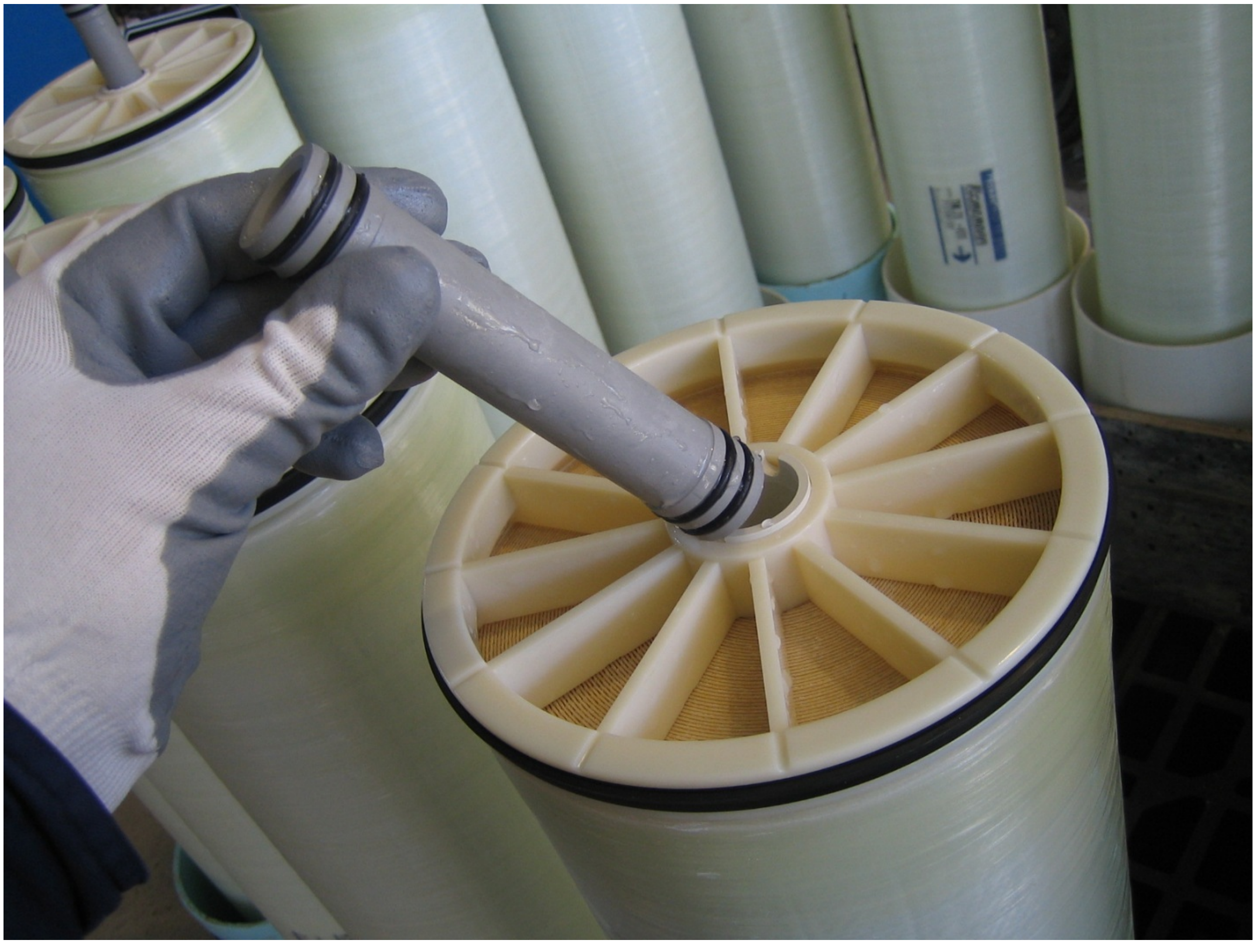
Prior to Installation

When RO elements are stored prior to installation or in transit to the plant site, they should be protected from direct sunlight and stored in a cool, dry place with an ambient temperature range of 68℉ to 95℉ (20℃ to 35℃). New elements are in heat sealed bags with storage solution.

Membranes without Brine Seals & Interconnectors

Membanes…

Installing interconnectors



Installing Brine seals…

Installing Thrust Rings…

Picture of stack of membranes as they are assembled with Brine seals & Interconnectors

Installing the last Membranes…

Resources Available on the internet…
Procedure for Elements Loading: http://www.membranes.com/docs/tsb/tsb122.pdf

3.3 Air Purge

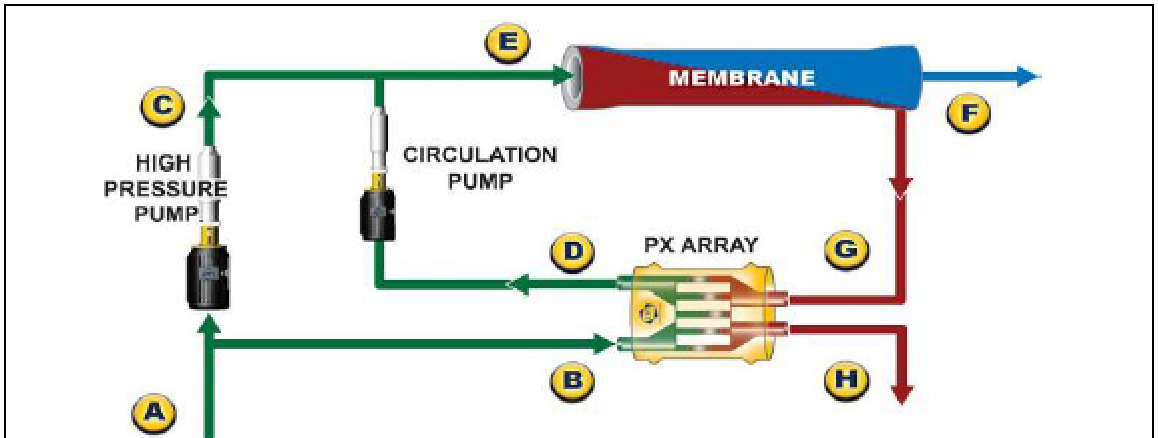
Before operating, purge all air from the RO as follows:

1. Make sure feed water meets the required pressure and quality standards.
2. Make provisions to divert permeate & drain flow to drain – use a temporary hose for that purpose.
3. Place the "SYSTEM" selector switch to "HAND".
4. Place all pumps selector switches on the control panel to "OFF".
5. Make sure the ON/OFF feed isolation valve is open, the ON/OFF PX bypass valve reject valve closed, and LP Brine out manual valve fully open
6. Start the feed pump first – select "HAND" on the selector switch located in the control panel.
7. Start PX recirculation booster pump - – select "HAND" on the HMI.
8. Run the system until all air has been purged.

3.4 Flow Balance

The next step is to balance the flow in & out of the PX system. This requires starting the RO HP pump and adjustment of valves throughout the system. The system is equipped with flowmeter on the permeate, LP Brine out, and HP Brine IN (to the PX).

PX® Energy Recovery Device System Analysis



		A	B	C	D	E	F	G	H
FLOW	US gpm	133	74	59	74	133	57	76	76
	m^3/hr	30	17	13	17	30	13	17	17
	m^3/day	725	403	322	403	725	312	413	413
PRESSURE	psi	26	26	766	729	766	0	743	15
	bar	1.8	1.8	52.8	50.3	52.8	0.0	51.2	1.0
QUALITY	ppm	36,000	36,000	36,000	38,434	36,958	200	64,687	62,312

Figure 3: PX Flow Settings

9. Start the RO HP pump by selecting "HAND" on the HMI.

10. Start closing the manual valve on the LP brine out from the PX until the flow reading on the HMI is close to 17.3 m³/hr or 76 gpm.

11. Check if permeate flowrate from permeate is close to 13 m³/hr or 57 gpm.

12. Adjust the VFD for the RO HP Pump until you get the flowrates as shown in Figure 3. The required speed for the RO HP Pump is a function of the rated flow, rated motor speed, and desired flow. For this pump, the rated flow is approximately 13 m³/hr or 57 gpm, the rated speed of the motor is 1000 RPM, and the desired flow is 17 m³/hr or 74 gpm (Stream D). In this system, the required RPM is 1298 RPM (74 gpm x 1000 RPM / 57 gpm). The pump curve for the RO HP Pump is included in Appendix B.

$$\text{Required RPM} = \frac{\text{Desired Flow x Rated RPM}}{\text{Rated Flow}}$$

13. Adjust the VFD for the PX Booster pump until you get the flowrates as shown in Figure 3. Since there is no flowmeter on the line for Stream E, you need to rely on the pressure reading at the discharge of the PX Booster pump. Please refer to Appendix C for the pump curve.

14. Once all parameters are set, keep running the system for 24 hours per manufacturer recommendations. In the meantime, do & check the following:

    a) Check for leaks and tighten all loose bolts & nuts

    b) Check permeate conductivity on the instrument. Again check this conductivity using a portable unit such as Myron L. If the two readings differ more than ± 2%, the sensor on the skid must be re-calibrated. Record this conductivity for normalization purposes.

    c) Check temperature reading (AIT-). Again verify the calibration of this sensor using the same portable unit (Myron L).

    d) Check feed water conductivity using portable conductivity monitor. These data will be used as a basis for normalizing RO operation later on.

    e) Calculate differential pressure ΔP between membrane feed pressure (PIT-) and reject pressure (PIT-). Record this pressure.

    f) Record ~~RO HP pump suction pressure or~~ cartridge filter discharge pressure (PI-), and filtered water pressure (PI-).

    ~~g) On the HMI, shut down RO HP pump and open the auto-flush valve and check visually if it is open. Check the flowrate during flushing.~~

    ~~h) On the HMI, set the selector switch for the permeate dump valve and check if the valve open – the water should be diverted to drain.~~

i) Check the feedwater isolation valve V-xxx if it is working. Shut down the RO HP pump (put selector switch to OFF) and check if the valve closes automatically.

3.5 Setting-up the Antiscalant Metering Pump

Adjusting the flowrate of metering pump requires two steps:

- Estimate dilution rate in the chemical tank (because pump flowrate requirement is below rated metering pump flowrate)
- Estimate preliminary speed % & stroke %
- adjusting metering pump flowrate based on line pressure

Antiscalant comes in 55-gallons drum (100% concentration), or 5-gallons jug of concentrated solution (20 x fold) to save on shipping.

The metering pump's rating is shown below:

1. Manual Stroke/Manual Frequency
2. Rated at 0.25 GPH/6 GPD/0.9 LPH
3. Strokes per Minute: 125 Max.

Let's assume we are going to dilute the antiscalant to 10% in the tank. At 10% concentration, the specific gravity of the solution is approximately the same as water. To estimate the metering pump settings (stroke speed & if necessary stroke speed), you need the following information:

- Concentration of chemical in the tank
- Final concentration of chemical required
- Flowrate of water in the main line or process line

Assuming specific gravity is close to water, we can calculate the flow of the metering pump required without resorting to a mass balance using this formula:

$$C_i \text{ x } m_i = C_f \text{ x } m_f \Rightarrow m_i = \frac{C_f \text{ x } m_f}{C_i}$$

Where

- "i" denotes initial & "f" final
- C = Concentration in unit of mg/liter
- m = Flowrate in GPH (Gallons per Hour) or LPM (liters per minute)

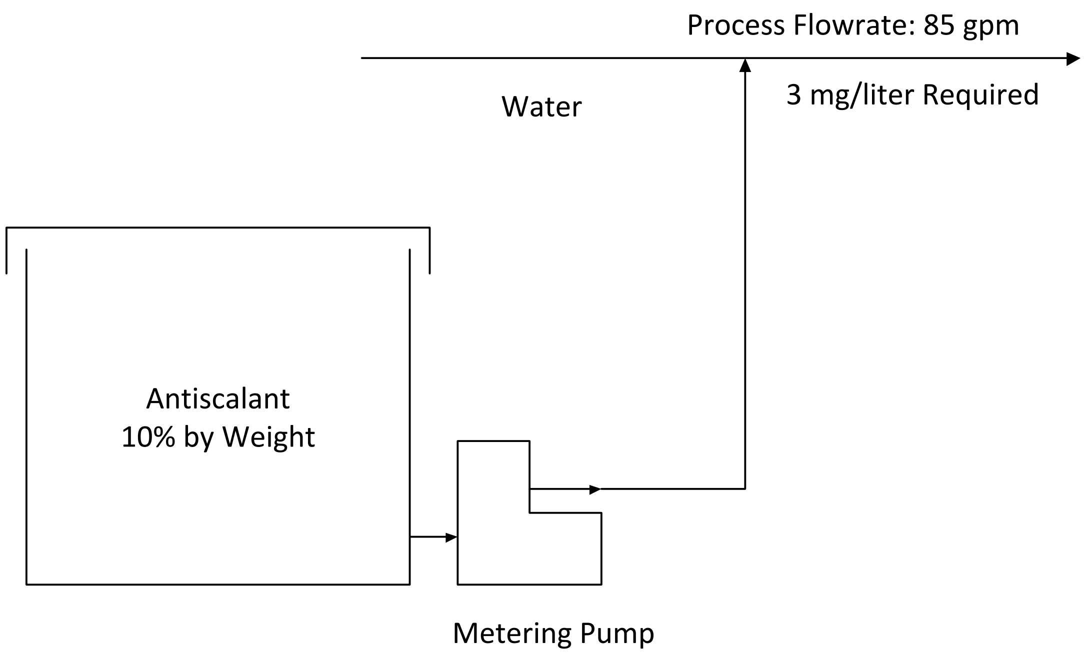
Because of the small flowrate, calculations using liters per minute (or even milli-liters per minute) for flow, and milli-grams/liter for concentration, is more convenient. The table below shows the conversion rate for all other units.

Parameter	Primary Unit	Actual Unit	Conversion
Flow	Liters per Minute (l/m)	gpm (gallons/minute) m^3/hr (cubic meter per hour)	gpm x 3.785 m^3/hr x 16.7
Concentration of Chemical in Tank	Milli-gram/liter (mg/l)	% Wt	% Wt (fraction) x S.G. x 1,000,000 (see note 1)

Notes:

1. If you have a 1% by weight chemical in the tank and specific gravity (S.G.) equal to 1, multiply 0.01 x 1 x 1,000,000 = 10,000 mg/l. At 10% by weight, the corresponding concentration is 100,000 mg/l.

Calculate the flowrate required from the metering pump for this plant based on the figure below:



<u>Calculations</u>
RO Feed flowrate = 85 gpm
Assume that the additional flow from the metering pump is negligible, So
85 gpm = 85 x 3.785 LPM = 321.7 LPM (liters/minutes)

m_i = (3 x 321.7)/100,000 = 0.009651 LPM ⇨ 0.009651 LPM x 60 minutes/hour = 0.579 LPH

Stroke Frequency at 100% x 100% Stroke Length = 0.9 LPH (See rating of the pump)
Stroke Frequency at X% x 100% Stroke Length = 0.579 LPH

If we leave the stroke length at 100%, the only variable that needs to change is the speed of the pump (SPM or Strokes per minute).

Since the ratio of 0.579/0.9 = 0.64 or 64% ⇨ The pump will operate at 64% stroke freq.
Since the max. SPM = 125 (See rating of the pump) ⇨ The pump will operate at 80 SPM (125 x 0.64)

In general, you should always change pump speed first and resort to changing stroke length only when the SPM goes below 20. If you have to change the stroke length:

Assume the ratio of required flow to max. flow is 0.25 ⇒ Stroke % x Stroke Speed = 0.25 or Stroke Speed = 0.25 / Stroke %. If you want to set the pump @ 50% stroke adjustment, the stroke speed is 0.25/0.5 = 0.50 or 50%. Since the pump is rated at 125 strokes per minute maximum, this corresponds to roughly 63 strokes per minute.

3.6 Initial Feed Water Tests

Before switching everything to AUTO, perform the following feed & permeate water tests and record the results to ensure that the feed water entering the RO system meets the specifications listed in "System Description."

Check	Equipment Required
Feedwater conductivity	Myron-L hand held conductivity monitor
Feedwater pH	pH reagent kit or Myron- L hand held conductivity / pH / Temp. monitor
Feedwater Chlorine Level	Chlorine reagent kit
Full blown water analysis	Chemistry Laboratory
~~Check SDI~~	~~SDI test kit~~
~~Check Turbidity (if possible)~~	~~Turbidity meter~~

4 CIP OPERATION

Over time, membranes are subjected to fouling due to the presence of suspended or sparingly soluble materials that may be present in the feedwater. Common examples of foulants are:

- Calcium carbonate scale
- All sulfate scales: Calcium, Barium, & Strontium
- Metal Oxides (iron & manganese mainly)
- Polymerized Silica Scale
- Inorganic colloidal deposits
- Mixed inorganic/organic colloidal deposits
- NOM (Natural Organic Material)
- Man-Made organic material (antiscalants/dispersants, cationic polyelectrolytes)
- Biological (Bacterial bioslime, algae, mold, or fungi)

When to perform CIP?

1. When normalized permeate flow decrease is less than 10%

2. When normalized permeate quality decrease is less than 10%

3. When normalized pressure drop, as measured between the feed and concentrate headers, increase is less than 15%

Fouling causes normalized conductivity and/or high pressure drop to increase gradually, and usually affect all membranes, or lead element membranes or last stage membranes. Table 24 shows a guideline from various RO membrane manufacturers about the possible type of foulants that may affect certain membranes depending on their location, and their effect on Normalized ΔP, or salt passage or permeate flow. To analyze the type of foulant, the worst effected membrane is removed and sent for an autopsy whereby the membrane manufacturer or other companies specialized in this field, dissects the membrane and look for the source of the foulants. In Appendix F, we have included an autopsy report to illustrate the complexity and the different types of procedures included in this report.

In Seawater systems, fouling is mostly caused by biological growth on the surface of the membranes.

In Table 3 below addresses all fouling types in brackish water systems where there are typically 2-stages for a typical RO. Seawater systems however have only one stage, so fouling will occur mostly within the first membranes or the last membranes instead of 1st stage and last stage.

Table 3: Fouling Types

Possible Cause	Location	Normalized Pressure Drop	Normalized Pressure Flow	Normalized Salt Passage
Metal Oxide	1st Stage	Normal to In-	Decreased	Normal to in-

		creased		creased
Colloidal Fouling	1st Stage	Normal to Increased	Decreased	Normal to increased
Scaling	Last Stage	Increased	Decreased	Normal to increased
Biological Fouling (biofilms)	Any Stage	Normal to Increased	Decreased	Normal to increased
Organic Fouling	All Stages	Normal	Decreased	Normal to increased
Oxidant	1st Stage Most Severe	Normal to Decreased	Decreased	Normal to increased
Abrasion (Carbon, Silt)	1st Stage Most Severe	Decreased		
O'Ring or glue leaks	Random			
Recovery Too High	All Stages	Normal to increased	Decreased	Normal to increased

For extensive information about this subject, refer to Hydranautics TSB-107 (Technical Service Bulletins # 107). TSB-107 is "Foulants and Cleaning Procedures" which you can access on the internet thru this link http://www.membranes.com/docs/tsb/tsb107.pdf. Due to the importance of this subject, we have included this section as part of this submittal.

What is normalized Flow or Pressure?
When you start the system, and after the RO starts providing consistent flow, a full blow analysis is required for feed which is used as the baseline for the performance of the RO when the membranes are new. As time goes by, the performance begins to decline and actual values of permeate conductivity, differential pressure, fouling, temperature changes, etc. These values are normalized using a program. Hydranautics offers RODATA excel spreadsheet to track the performance of the RO which you can download from their website at http://www.membranes.com/index.php?pagename=rodata.

For this system, the CIP flow required is 18.2 m³/hr (80 gpm) CIP flow @ 1.37 to 4.13 barg (20 – 60 psig).

5 MAINTENANCE

In this section, we will describe & include the following:

- Maintenance Log Sheet: Log Sheet provided to record all system performance. Copy and use them to record data
- RO Membrane Replacement: This section describes the procedure required to remove RO membranes
- General Procedures for Storage of RO Membranes: This section describes the two procedures required to store RO membranes for the short & the long terms
- What is Normalization: Describes the procedure required to normalize data in order to predict RO performance
- Procedure for Antiscalant: Describe a procedure to test a new Antiscalant that is not approved by RO membranes manufacturer
- Spare Parts Required: List of spare parts required for this plant
- List of Consumable: List of consumable required for this plant
- Field Testing Equipment: Describes the various testing equipment that customer should have at site
- Sensors Calibration

5.1 Maintenance Log Sheet

The RO Water System requires scheduled maintenance on a daily, weekly and monthly basis. Test feed water parameters, and observe system performance regularly to maintain operating efficiency, maximum membrane life and warranty protection. Record all system data in a maintenance log. The prescribed maintenance program is designed to ensure that the feed water meets the specifications despite seasonal and unexpected changes in the feed water quality.

Parameter	Daily	Weekly	Monthly
Differential Pressure Across Filter	~~√~~		
Differential Pressure Across Cartridge Filter	√		
pH of feed water	√		
Conductivity of feed water	√		
Temperature of feed water	√		
~~Total chlorine of feed water~~	~~√~~		
Silt Density Index (SDI) of feed water		√	
Conductivity of permeate		√	
% Salt Rejection of product		√	
Permeate Flowrate			√
Reject Flowrate			√

Table 4: Maintenance Log Sheet Cable

Recorded by:	Date:							
Parameter	Instrument	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Feedwater SDI	SDI Test Kit							
Feedwater Turbidity	Hand Held							
Inlet Pressure	PI							
Outlet Pressure	PI-							
Differential Pressure								
Antiscalant Pump Stroke Setting								
Feed water pH	AIT-							
Feedwater Conductivity	Hand Held							
Feedwater Temperature	"							
Feed Water Pressure								
Permeate Conductivity	CIT-							
Membrane Feed Pressure	PT-							
Reject Line Pressure PX HP IN	PT-							
Permeate Flowrate								
Reject Flowrate								
Permeate Conductivity	CIT-							

5.2 RO Membrane Replacement

Membrane replacement frequency depends on the feed water quality. Replace the membranes when the permeate quality falls below the required level, and when cleaning and sanitization fail to restore the desired values. Remove and discard used membranes, retaining the interconnectors and end plugs. The RO system is a reject-staged system. The orientation of membranes in the housings is critical to the proper operation of the system. Refer to process and instrumentation drawings for proper orientation of membranes and housing components.

Note: All membranes must be replaced at the same time.

5.3 General Storage Procedures for RO Membranes

The general storage procedures included in this section are as follows:

1. Short-Term storage of RO membrane elements in place in pressure tubes.
2. Long-Term storage of RO membrane elements in place in pressure tubes.
3. Dry storage of RO membrane elements as spares or before start-up of an RO plant.

The composite polyamide type of RO membrane elements may not to be exposed to chlorinated water under any circumstances. Any such exposure will cause irreparable damage to the membrane. Absolute care must be taken following any disinfection of piping or equipment or the preparation of cleaning or storage solutions to ensure that no trace of chlorine is present in feedwater to the RO membrane elements. If there is any doubt about the presence of chlorine, perform chemical testing to make sure. Neutralize any chlorine residual with a sodium bisulfite solution, and ensure adequate contact time to accomplish complete dechlorination.

5.3.1 Short-Term Storage

Short-Term Storage is for periods where an RO plant must remain out of operation for more than five (5) days, but fewer than thirty (30) days, with the RO elements in place. Prepare each RO train as follows:

1. Flush the RO section with feedwater, while simultaneously venting any gas from the system.
2. When the pressure tubes are filled, close the appropriate valves to prevent air from entering the systems.
3. Reflush as described above at 5-day intervals.

5.3.2 Long-Term Storage

Long-term storage is for periods where an RO plant must remain out of operation for more than thirty (30) days with the RO elements in place. But before we describe the procedure, here is a description of possible solutions that you can use to preserve membranes for long periods.

5.3.3 Recommended Biocides for Disinfection & Storage of Membranes

Chemical	Preparation
Sodium Bisulfite	Sodium Bisulfite can be used as an inhibitor of biological growth. To control biological growth with sodium bisulfite, it is applied at a dosing rate of 500 ppm for 30 to 60 minutes daily. Sodium bisulfite at a 1% concentration can also be used as a preservative during long term storage of the membrane elements.
Formaldehyde	Formaldehyde solution of 0.1 to 1.0 % concentration may be used for system disinfection and as a preservative for long term storage. The membrane elements should be operated for at least 24 hours before being exposed to formaldehyde.
Isothiszolin	Manufacturers of water treatment chemicals under the trade name Kathon distribute Isothiszolin. The commercial solution contains 1.5% of the active ingredient. The recommended concentration of Kathon for disinfection and storage is 15 to 258 ppm.
Hydrogen Peroxide	Hydrogen Peroxide or a solution of hydrogen peroxide with paracetic acid can be used for disinfection. Special care must be taken that transition metals (Fe, Mn) are not present in the feed water, since in the presence of transition metals oxidation of the membrane surface may occur resulting in membrane degradation. The concentration of hydrogen peroxide in the disinfecting solution should not exceed 0.2%. Hydrogen peroxide should not be used as a preservative for long term storage of membrane elements. During application of hydrogen peroxide the water temperature should not exceed 25°C.

5.3.4 Procedure

Prepare each train as follows:

1. Clean the RO membrane elements in place.
2. Flush the RO section with the approved biocide (See section below) prepared from permeate.
3. When the RO section is filled with this solution (make sure that it is completely filled), close the valves to retain the solution in the RO section.
4. Repeat Steps 2 and 3 with fresh solution every thirty (30) days if the temperature is below 27°C, or every fifteen days if the temperature is above 27°C.
5. When the RO system is ready to be returned to service, flush the system for approximately one hour using low-pressure feedwater with the product dump valve open to drain; then flush it at high pressure for 5 to 10 minutes with the product dump valve open to drain. Before returning the RO system to service, check for any residual biocide in the product.

5.4 Normalization

The majority of reverse Osmosis (RO) systems normally will operate under fairly steady condition over long periods of time if operating parameters remain constant. Fouling does not occur, and membrane damage is avoided.

Unfortunately, operating parameters (e.g. temperature, feed TDS, permeate flow, recovery) do change, and fouling of the membrane and element feed path can occur. Normalization is a technique that allows the user to compare operation at a specific set of conditions to as reference set of conditions. This allows the user to determine whether changes in flow or rejection are caused by fouling, damage to the membrane, or are just due to different operating conditions.

As mentioned before, Hydranautics offers a macro based Excel spreadsheet called RODATA to track RO performance.

5.4.1 Changes in Apparent Membrane Performance

Changes in operating parameters will have a normal effect on membrane performance. These influences can either result in an apparent reduction of permeate flow or quality. This section will enumerate those effects that normally affect membrane performance.

5.4.1.1 Loss of Flow

The following changes in operating parameters will decrease the actual permeate flow of a system:

- A decrease in feed water temperature with no change in feed pump pressure.
- A decrease in RO feed pressure by throttling down the feed valve.
- An increase in permeate backpressure with no change in feed pump pressure.
- An increase in the feed TDS (or conductivity) since this increases the osmotic pressure that has to be overcome to permeate water through the membrane
- An increase in system recovery rate. This increases the average feed/concentrate TDS which then increases the osmotic pressure.
- Fouling of the membrane surface.
- Fouling of the feed spacer that results in an increase of feed-to-concentrate pressure drop (delta P), which starves the back-end of the system of net driving pressure (NDP) to produce permeate water.

5.4.1.2 Loss of Water Quality

The following changes in operating parameters will result in actual lower quality permeate water, as indicated by an increase in permeate TDS as ppm or conductivity:

- An increase in feed water temperature with the system adjusted to maintain the same permeates flow (or flux).
- A decrease in the system permeates flow, which reduces the water flux, and results in less permeate water to dilute the amount of salts that have passed through the membrane.
- An increase in the feed TDS (or conductivity) since the RO will always reject a set percentage of the salts.

- An increase in the system recovery rate since this increases the average feed / concentrate TDS of the system.
- Fouling of the membrane surface.
- Damaged O-Rings seals.
- Damage to the membrane surface (such as exposure to chlorine), which allows more salts to pass.
- Use of the normalization program thus "factors out" the effects of changing feed pressure, concentration, and temperature. Factors related to fouling, degradation, or systemic factors (i.e., blown o-rings) are thus more clearly discerned.
- Normalized data that is graphed will show not only the instantaneous condition of the RO system at any given time, but also shows the detailed operating history. These graphs can be a useful tool for troubleshooting.

5.4.2 Normalization Data

The normalization data graphs can be easily generated for you upon request. Typical graphs will show:

Normalized Salt Passage vs. Time:	This graph plots the normalized percent salt passage of the system relative to the system reference data at start-up.
Normalized Permeate Flow vs (versus) Time	This graph plots the normalized permeate flow in gpm or m3/hr, relative to the system reference data at start-up.
Salt transport Coefficient versus (vs.) Time	This graph plots Salt Transport Coefficient (STC) for "membrane technophiles". The importance of this number is that it measures the efficiency of the membrane in how fast it allows the passage of salts. The value is reported as m/sec (meters per second). This number allows the comparison of membranes from site to site, independent of what the onsite operating conditions are. This number will be affected by changes in the ionic makeup of the feed water. For example, an increase in divalent ions (like hardness or sulfate) will result in lower Salt Transport Coefficient.
Water Transport Coefficient vs. Time	This graph plots the water transport coefficient (WTC) for "membrane technophiles". The importance of this number is that it measures the efficiency of the membrane in how fast it allows the passage of water. The value is reported as m/sec-kPa (meters per second per kilopascal. This number allows the comparison of membranes from site to site, independent of what the on site operating conditions are.
Normalized ΔP vs Time	This graph plots the normalized feed-to-concentrate pressure drop in PSI or bar relative to the system reference data at start-up. The normalized Delta P value reflects adjustments to pressure drop to varying feed and concentrate flows.

6 TROUBLESHOOTING

The problems associated with operation of RO can be classified into three categories:

1. PX
2. Instrumentation
3. O-ring leakage
4. Fouling
5. Mechanical

6.1 PX

This section is taken from the "INSTALLATION, OPERATION, & MAINTENANCE MANUAL PX-Series (25-120 gpm units)".

SYMPTOM	PROBABLE CAUSE	CORRECTIVE ACTION
Excessive noise levels	1. Operating PX unit(s) beyond rated flow rates on its low-pressure and/or the high pressure sides.	Immediately reduce flow rate through adjustment of PX booster pump and LP control valve and balance the system.
	2. Insufficient back pressure at low pressure outlet.	Increase feed pressure at the low pressure inlet and throttle the flow accordingly.
Excessive high pressure in RO system	1. Main high-pressure pump is operating at too high a flow rate.	Determine 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 RO system.	Increase PX booster pump flow rate and low pressure control valve flow rate and balance system.
	3. Low pressure seawater feed flow is less than high pressure reject water outlet flow creating mixing and high outlet salinity.	See section 6.2 (refer to Appendix
	4. A jammed or stalled rotor short circuits high pressure reject water with high pressure feed water and no exchange occurs. (PX audible noise will	See symptom D.

SYMPTOM	PROBABLE CAUSE	CORRECTIVE ACTION
	be absent)	
High Salinity in high pressure seawater feed stream.	1. Unbalanced system 2. A jammed or stalled rotor short circuits high pressure reject water with high pressure feed water and no exchange occurs. (PX audible noise will be absent) 3. Operating PX unit(s) below rated flow rate results in low RPM resulting in increased mixing. 4. Malfunctioning and/or stalled PX booster pump.	See section 6.2 See symptom D. Increase H.P. seawater flow through PX booster pump. (Lower system recovery) Check PX booster pump's rotation, operation, flows, and pressures.
Stalled Rotor. **1. No audible rotation** **2. Seawater at LP outlet** **3. Reject water at HP outlet**	1. After prolonged shutdowns biological growth can cause the rotor to stick 2. Operating system above rated pressure and flow capacity or below rated flow capacity. 3. Foreign debris or particles lodged in device. 4. System is not properly flow balanced.	See disassembly and repair section 8 and remove access cover and check rotation. See table 4.1 See disassembly and repair section 8. See Section 6.2.
Irregular audible rotation. (putt, putt, putt)	1. Chipped / broken rotor ducts.	See disassembly and repair section 9 or 10.
Cannot build system pressure and/or excessive leakage.	1. High pressure pump failure. 2. Open valve or leak in high- pressure system. 3. Excessive leakage from high pres-	Check high pressure pump performance. 1. Check valve orientations. 2. Check membrane product tube interconnections. 1. See disassembly and repair

SYMPTOM	PROBABLE CAUSE	CORRECTIVE ACTION
	sure to low pressure within PX.	section 9 or 10 and check of damaged components.
Low high pressure reject flow.	1. Excessive differential pressure losses through RO membranes. 2. Malfunctioning and/or stalled PX booster pump.	Clean RO membranes. Check PX booster pump's operation, flows, and pressures.
Abnormal pulsations or vibration.	Air in system.	Bleed and purge all air from the system before applying high pressure.
External leakage and/or drips	1. Damaged O-rings. 2. Scratches inside pressure vessel. 3. Damaged low-pressure nipple adaptor on low- pressure foundation (PX-60).	Check and replace defective and/or suspected O-rings. Sand vessel sealing surface clean and smooth. Remove foundation and check the 2 nipples for cracks or damage.

6.2 Instrumentation

Instrumentation can cause a lot of problems. The biggest problems associated with troubleshooting an RO, especially during start-up, are erroneous readings of flow from magnetic and paddle wheel flowmeters. With pipes full of air at the beginning, you should expect a lot of error in flowrate readings until the RO have run for some time and all air has been evacuated from the system. A clamp-on type ultrasonic flowmeter that can detect flow thru pipes is the best option available to verify the accuracy of flowmeters– but these are very expensive instrument, and it is best that can be rented or borrowed from large utility whenever possible. Wrong calibration and air bubbles are the primary causes of wrong instrument reading. Air bubbles cause wild fluctuations in flow readings.

Pressure transmitters are usually trouble free, but we have seen big difference between pressure gauges and pressure transmitter readings on the same location. If the pressure gauge has 1% built-in error and pressure transmitter has 0.5% error and the difference is too high, a pressure transmitter must be checked with calibrated pressure gauge.

Conductivity and pH instruments can easily be verified with potable Conductivity/pH unit such as Myron L Ultrameter instrument thru a sample valve.

6.3 O-Ring Leakage

O-ring leakage occurs abruptly – not over time, so it is easy to detect in most cases. O-ring leak age can easily be verified with the process of probing.

The membranes are connected together with interconnector which has two o-rings as we mentioned before. This is where the most problem occur when an RO HP pump starts without VFD. The cause of O'-ring leakage may occur at the beginning during start-up when loading the membranes, or when the pump starts pushing the membrane forward within the vessels from the feed end to the opposite end. This is the main cause of the so called "O-rings" leakage.

6.3.1 Probing

If conductivity from a pressure vessel is slightly higher than the others, the pressure vessel must be probed. Probing of the pressure vessel is a procedure whereby one isolate the pressure vessel from the permeate manifold, insert a long ¼" or ⅜" tube along the length of the entire pressure vessel, and start taking conductivity reading from the end and at 20" interval as you withdraw the tubing within the vessel. Probing allows operator to identify the problem if it is from O-ring leak, or bad membrane. If it happens where one pressure vessel shows higher conductivity at all times as other pressure vessels, and probing shows no sign of O-ring leakage, it may very well that the worst membranes supplied by manufacturer were loaded in that vessel by accident. This can be detected by looking at the chart recorded for the location of membranes in this pressure vessel and the data from the wet test provided by the RO manufacturer. This is a good article written about the probing procedure by Filmtec.
http://www.dow.com/PublishedLiterature/dh_003d/0901b8038003d377.pdf?filepath=liquidseps/pdfs/noreg/609-02111.pdf&fromPage=GetDoc

Another resource is also available from Hydranautics, refer to TSB114 (Technical Service Bulletins):
http://www.membranes.com/docs/tsb/tsb114.pdf

On the right, you see a picture for a probing valve taken from Protec Probing valve brochures. You can access this datasheet at the Protec website.

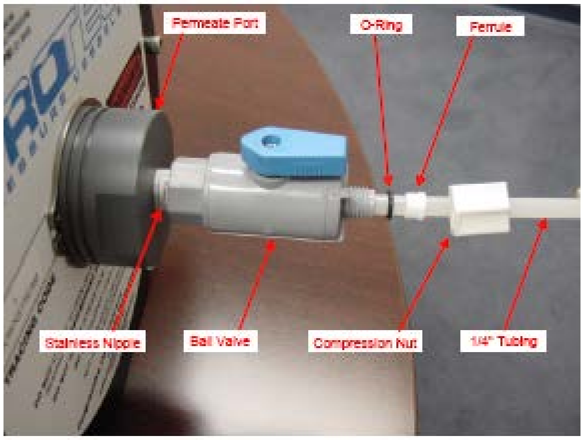


Figure 4 shows how to probe a 7M (&-elements long) pressure vessel at various points.

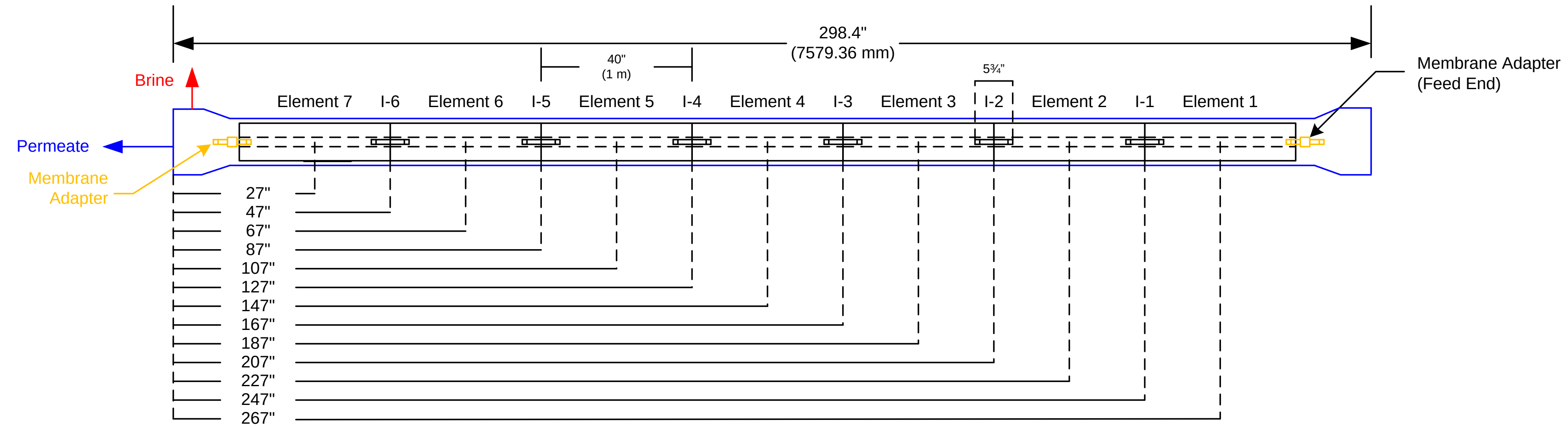


Figure 4: Probing Pressure Vessels

6.4 Membrane Autopsy

Membrane autopsy is a destructive test conducted on fouled membrane. Autopsy is a very complicated process involving different type of procedures to determine the presence of specific foulants on the membrane surface. The procedures consist of series of destructive test conducted on the membrane at laboratories or companies that specializes in these tests. The procedures are listed below:

1. Visual inspection
2. Weight measurement
3. Bubble test
4. Acid test
5. Flat sheet testing flow rate and rejection
6. Dye testing
7. Fujiwara test
8. EDS or Energy Dispersive spectroscopy
9. SEM or Scanning Electronic Microscopy
10. FTIR or Fourier Transform Infrared Spectrometer

Instead of explaining what these complicated tests, Appendix I shows a report for small two-pass seawater systems with break tank in the middle. The seawater is pumped from wells which apparently had a lot of Hydrogen Sulfide that was not reported in the original water analysis. The location of the system is the Grand Bahamas. The two membranes tested are the 1st pass RO membrane SWC3 and the 2nd pass RO membrane ESPA2. Notice how the combination of Iron & bacteria have fouled the first pass membrane (orange color = Brown color from organic sources and Red color from Iron presence), and the black sulfur powder collected on the 2nd pass membrane (This is when elemental sulfur has collapsed on the 2nd pass due to effect of low pH on hydrogen sulfide coming out of the well).

When an RO system operates at high differential pressure, and the RO train permeates decreases, there will be a point where the differential pressure across the membranes exceeds the 10 psi limit which will cause telescoping. Telescoping causes the leaves of the membranes to protrude outward breaking along the way the outer Fiberglass wrapping.

Appendix A
Instruction Manuals for Major Components

Water Equipment Technologies
580 Village Blvd, Suite 310, W Palm Beach, FL 33409
TEL +1.561.684.6300 FAX +1.561.471.0629

Here is a link to Instructions Manuals for most equipment.

Component	Manufacturer	Model or Part No.	Link to Datasheet/O&M on the Internet
RO Cartridge Filter Housing	FSI	XL234	http://www.fsifilters.com/assets/files/literature/manuals/XL234_manual.pdf
RO Pressure Vessels, 1000psi	Protec	8-1000-SP	
RO HP Pump	Danfoss	APP 16	http://www.danfoss.com/NR/rdonlyres/C2BED4EC-595D-483D-8C43-A20CCF640AC4/0/180R9265_IOMAPPPumps1622_UK.pdf
PX Unit	ERI	PX-90S	Refer to Appendix C
PX Booster Pump	ERI	HP-1253	
Feedwater Pump	Ampco	RCH2 3x3-7	
CIP/Flushing Pump	G&L	33SV	http://documentlibrary.xylemappliedwater.com/wp-content/blogs.dir/22/files/2012/07/IM235R01.pdf
Metering Pumps	Pulsafeeder		http://pulsatron.salesmrc.com/pdfs/pulsatron_series_iom.pdf
Pressure Transmitters	KPSI	T-342-101500	
Pressure Switch, Low-pressure switch on the suction of the RO HP Pump	Barksdale	PH90	
Pressure Switch, High-pressure switch on the discharge of the RO HP pump	Neo-Dyn	132P-1500	http://www.neodyn.com/download/pdf/industrial/i&o%20manuals/181pc3.pdf
Flow Sensors – LP lines	GF/Signet	2536-PO	
Flow Sensors – HP lines	Blue-White		
Conductivity Instrument	GF/Signet	3-8860	http://www.gfps.com/content/gfps/signet/en_US/sensors/conduct/instruments/8860.html

Component	Manufacturer	Model or Part No.	Link to Datasheet/O&M on the Internet
PLC	Allen Bradley Micrologix 1200	1762-L40BWAR	http://literature.rockwellautomation.com/idc/groups/literature/documents/um/1762-um001_-en-p.pdf
HMI	Magelis	GTO 1310	http://www.schneider-electric.pl/documents/Polish_Catalogue/Instrukcja_Obslugi_GTO.pdf
VFD	Square D	ATV61	http://www.adara-bg.com/img/110113094817ATV61-Installationmanual.pdf

Appendix B
RO Projections & PX Projections

Permeate throttling(ALL STAGES) WITH Pressure/Work Exchanger

RO program licensed to:			
Calculation created by:			
Project name:	Carriacou	Permeate flow:	13.00 m3/hr
HP Pump flow:	13.2 m3/hr	Raw water flow:	30.2 m3/hr
		Permeate throttling(All st.)	1.0 bar
Feed pressure:	53.0 bar	Permeate recovery:	43.0 %
Feedwater Temperature:	25.0 C(77F)		
Feed water pH:	8.00	Element age:	0.0 years
Chem dose, ppm (100%):	0.0 H2SO4	Flux decline % per year:	5.0
		Fouling Factor	1.00
		Salt passage increase, %/yr:	7.0
Average flux rate:	10.4 gfd	Feed type:	Seawater-well or MF/UF Pretreatment

Stage	Perm. Flow m3/hr	Flow/Vessel Feed m3/hr	Flow/Vessel Conc m3/hr	Flux gfd	Beta	Conc.&Throt. Pressures bar	Conc.&Throt. Pressures bar	Element Type	Elem. No.	Array
1-1	13.0	10.1	5.7	10.4	1.01	51.6	1.0	SWC6 MAX	18	3x6

Ion	Raw water mg/l	Adjusted Water mg/l	Feed water mg/l	Permeate mg/l	Concentrate mg/l	ERD Reject mg/l
Ca	433.0	433.0	444.7	0.807	779.5	759.0
Mg	1330.0	1330.0	1365.9	2.479	2394.4	2331.2
Na	11086.0	11086.0	11383.1	98.983	19895.6	19372.3
K	398.0	398.0	408.6	4.439	713.6	694.8
NH4	0.0	0.0	0.0	0.000	0.0	0.0
Ba	0.052	0.052	0.053	0.000	0.094	0.1
Sr	0.000	0.000	0.000	0.000	0.000	0.0
CO3	15.9	15.9	16.6	0.000	35.4	34.2
HCO3	146.0	146.0	149.6	2.098	253.5	247.1
SO4	2787.0	2787.0	2862.2	5.590	5017.2	4884.7
Cl	19960.0	19960.0	20495.3	159.867	35836.1	34893.1
F	1.0	1.0	1.0	0.016	1.8	1.7
NO3	0.0	0.0	0.0	0.000	0.0	0.0
B	4.00	4.00	4.08	1.196	6.25	6.1
SiO2	1.0	1.0	1.0	0.01	1.8	1.7
CO2	0.74	0.75	0.75	0.75	0.75	0.75
TDS	36162.0	36161.9	37132.2	275.5	64935.2	63226.1
pH	8.00	8.00	8.00	6.66	7.92	

	Raw water	Feed water	Concentrate
CaSO4 / Ksp * 100:	22%	23%	47%
SrSO4 / Ksp * 100:	0%	0%	0%
BaSO4 / Ksp * 100:	209%	216%	410%
SiO2 saturation:	1%	1%	1%
Langelier Saturation Index	1.16	1.19	1.58
Stiff & Davis Saturation Index	0.21	0.23	0.56
Ionic strength	0.72	0.74	1.29
Osmotic pressure	26.4 bar	27.1 bar	47.4 bar

H.P. Differential of Pressure/Work Exchanger	0.5 bar	Pressure/Work Exchanger Leakage:	1 %
Pressure/Work Exchanger Boost Pressure	1.9 bar	Volumetric Mixing	6 %

Product performance calculations are based on nominal element performance when operated on a feed water of acceptable quality. The results shown on the printouts produced by this program are estimates of product performance. No guarantee of product or system performance is expressed or implied unless provided in a separate warranty statement signed by an authorized Hydranautics representative. Calculations for chemical consumption are provided for convenience and are based on various assumptions concerning water quality and composition. As the actual amount of chemical needed for pH adjustment is feedwater dependent and not membrane dependent, Hydranautics does not warrant chemical consumption. If a product or system warranty is required, please contact your Hydranautics representative. Non-standard or extended warranties may result in different pricing than previously quoted.
(8/63)

Permeate throttling(ALL STAGES) WITH Pressure/Work Exchanger

RO program licensed to:					
Calculation created by:					
Project name:	Carriacou		Permeate flow:	13.00	m3/hr
HP Pump flow:	13.2	m3/hr	Raw water flow:	30.2	m3/hr
			Permeate throttling(All st.)	1.0	bar
Feed pressure:	53.0	bar	Permeate recovery:	43.0	%
Feedwater Temperature:	25.0	C(77F)			
Feed water pH:	8.00		Element age:	0.0	years
Chem dose, ppm (100%):	0.0	H2SO4	Flux decline % per year:	5.0	
			Fouling Factor	1.00	
			Salt passage increase, %/yr:	7.0	
Average flux rate:	10.4	gfd	Feed type:	Seawater-well or MF/UF Pretreatment	

Stage	Perm. Flow m3/hr	Flow/Vessel Feed m3/hr	Flow/Vessel Conc m3/hr	Flux gfd	Beta	Conc.&Throt. Pressures bar	Conc.&Throt. Pressures bar	Element Type	Elem. No.	Array
1-1	13.0	10.1	5.7	10.4	1.01	51.6	1.0	SWC6 MAX	18	3x6

Stg	Elem no.	Feed pres bar	Pres drop bar	Perm flow m3/hr	Perm Flux gfd	Beta	Perm sal TDS	Conc osm pres	Ca	Mg	Cl	B	SiO2
									Cumulative Perm Ion levels				
1-1	1	53.0	0.3	1.5	22.0	1.06	99.6	31.9	0.30	0.94	56	0.48	0.00
1-1	2	52.6	0.3	1.1	15.8	1.04	124.8	36.6	0.38	1.17	70	0.58	0.00
1-1	3	52.4	0.2	0.8	10.8	1.03	154.7	40.7	0.47	1.45	87	0.71	0.00
1-1	4	52.1	0.2	0.5	6.7	1.03	191.4	43.7	0.58	1.79	107	0.86	0.00
1-1	5	51.9	0.2	0.3	4.3	1.02	231.7	45.9	0.70	2.16	130	1.02	0.01
1-1	6	51.7	0.2	0.2	2.9	1.01	274.1	47.4	0.84	2.56	154	1.19	0.01

Stage	NDP bar
1-1	14.3

Product performance calculations are based on nominal element performance when operated on a feed water of acceptable quality. The results shown on the printouts produced by this program are estimates of product performance. No guarantee of product or system performance is expressed or implied unless provided in a separate warranty statement signed by an authorized Hydranautics representative. Calculations for chemical consumption are provided for convenience and are based on various assumptions concerning water quality and composition. As the actual amount of chemical needed for pH adjustment is feedwater dependent and not membrane dependent, Hydranautics does not warrant chemical consumption. If a product or system warranty is required, please contact your Hydranautics representative. Non-standard or extended warranties may result in different pricing than previously quoted.
(8/63)

Permeate throttling(ALL STAGES) WITH Pressure/Work Exchanger

RO program licensed to:					
Calculation created by:					
Project name:	Carriacou		Permeate flow:	13.00	m3/hr
HP Pump flow:	13.2	m3/hr	Raw water flow:	30.2	m3/hr
			Permeate throttling(All st.)	1.0	bar
Feed pressure:	53.4	bar	Permeate recovery:	43.0	%
Feedwater Temperature:	25.0	C(77F)			
Feed water pH:	8.00		Element age:	1.0	years
Chem dose, ppm (100%):	0.0	H2SO4	Flux decline % per year:	5.0	
			Fouling Factor	0.95	
			Salt passage increase, %/yr:	7.0	
Average flux rate:	10.4	gfd	Feed type:	Seawater-well or MF/UF Pretreatment	

Stage	Perm. Flow	Flow/Vessel Feed	Flow/Vessel Conc	Flux	Beta	Conc.&Throt. Pressures		Element Type	Elem. No.	Array
	m3/hr	m3/hr	m3/hr	gfd		bar	bar			
1-1	13.0	10.1	5.7	10.4	1.01	52.0	1.0	SWC6 MAX	18	3x6

	Raw water	Adjusted Water	Feed water	Permeate	Concentrate	ERD Reject
Ion	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Ca	433.0	433.0	444.7	0.860	779.5	758.9
Mg	1330.0	1330.0	1365.9	2.642	2394.3	2331.1
Na	11086.0	11086.0	11382.9	105.466	19890.4	19367.4
K	398.0	398.0	408.6	4.730	713.3	694.6
NH4	0.0	0.0	0.0	0.000	0.0	0.0
Ba	0.052	0.052	0.053	0.000	0.094	0.1
Sr	0.000	0.000	0.000	0.000	0.000	0.0
CO3	15.9	15.9	16.6	0.000	35.3	34.2
HCO3	146.0	146.0	149.6	2.235	253.4	247.0
SO4	2787.0	2787.0	2862.2	5.957	5016.9	4884.4
Cl	19960.0	19960.0	20495.1	170.338	35827.7	34885.2
F	1.0	1.0	1.0	0.017	1.8	1.7
NO3	0.0	0.0	0.0	0.000	0.0	0.0
B	4.00	4.00	4.07	1.267	6.19	6.1
SiO2	1.0	1.0	1.0	0.01	1.8	1.7
CO2	0.74	0.75	0.75	0.75	0.75	0.75
TDS	36162.0	36161.9	37131.7	293.5	64920.8	63212.5
pH	8.00	8.00	8.00	6.68	7.92	

	Raw water	Feed water	Concentrate
CaSO4 / Ksp * 100:	22%	23%	47%
SrSO4 / Ksp * 100:	0%	0%	0%
BaSO4 / Ksp * 100:	209%	216%	410%
SiO2 saturation:	1%	1%	1%
Langelier Saturation Index	1.16	1.19	1.58
Stiff & Davis Saturation Index	0.21	0.23	0.56
Ionic strength	0.72	0.74	1.29
Osmotic pressure	26.4 bar	27.1 bar	47.4 bar

H.P. Differential of Pressure/Work Exchanger	0.5	bar	Pressure/Work Exchanger Leakage:	1 %
Pressure/Work Exchanger Boost Pressure	1.9	bar	Volumetric Mixing	6 %

Product performance calculations are based on nominal element performance when operated on a feed water of acceptable quality. The results shown on the printouts produced by this program are estimates of product performance. No guarantee of product or system performance is expressed or implied unless provided in a separate warranty statement signed by an authorized Hydranautics representative. Calculations for chemical consumption are provided for convenience and are based on various assumptions concerning water quality and composition. As the actual amount of chemical needed for pH adjustment is feedwater dependent and not membrane dependent, Hydranautics does not warrant chemical consumption. If a product or system warranty is required, please contact your Hydranautics representative. Non-standard or extended warranties may result in different pricing than previously quoted.
(8/63)

Permeate throttling(ALL STAGES) WITH Pressure/Work Exchanger

RO program licensed to:					
Calculation created by:					
Project name:	Carriacou		Permeate flow:	13.00	m3/hr
HP Pump flow:	13.2	m3/hr	Raw water flow:	30.2	m3/hr
			Permeate throttling(All st.)	1.0	bar
Feed pressure:	53.4	bar	Permeate recovery:	43.0	%
Feedwater Temperature:	25.0	C(77F)			
Feed water pH:	8.00		Element age:	1.0	years
Chem dose, ppm (100%):	0.0	H2SO4	Flux decline % per year:	5.0	
			Fouling Factor	0.95	
			Salt passage increase, %/yr:	7.0	
Average flux rate:	10.4	gfd	Feed type:	Seawater-well or MF/UF Pretreatment	

Stage	Perm. Flow m3/hr	Flow/Vessel Feed m3/hr	Flow/Vessel Conc m3/hr	Flux gfd	Beta	Conc.&Throt. Pressures bar	Conc.&Throt. Pressures bar	Element Type	Elem. No.	Array
1-1	13.0	10.1	5.7	10.4	1.01	52.0	1.0	SWC6 MAX	18	3x6

Stg	Elem no.	Feed pres bar	Pres drop bar	Perm flow m3/hr	Perm Flux gfd	Beta	Perm sal TDS	Conc osm pres	Ca	Mg	Cl	B	SiO2
									Cumulative Perm Ion levels				
1-1	1	53.4	0.3	1.5	21.4	1.06	108.9	31.8	0.33	1.02	61	0.52	0.00
1-1	2	53.0	0.3	1.1	15.6	1.04	135.5	36.4	0.41	1.27	76	0.63	0.00
1-1	3	52.8	0.2	0.8	10.9	1.03	166.9	40.4	0.51	1.56	94	0.76	0.00
1-1	4	52.5	0.2	0.5	6.9	1.03	205.2	43.5	0.62	1.92	115	0.92	0.00
1-1	5	52.3	0.2	0.3	4.6	1.02	247.4	45.8	0.75	2.31	139	1.09	0.01
1-1	6	52.1	0.2	0.2	3.1	1.01	292.0	47.4	0.89	2.73	164	1.26	0.01

Stage	NDP bar
1-1	14.8

Product performance calculations are based on nominal element performance when operated on a feed water of acceptable quality. The results shown on the printouts produced by this program are estimates of product performance. No guarantee of product or system performance is expressed or implied unless provided in a separate warranty statement signed by an authorized Hydranautics representative. Calculations for chemical consumption are provided for convenience and are based on various assumptions concerning water quality and composition. As the actual amount of chemical needed for pH adjustment is feedwater dependent and not membrane dependent, Hydranautics does not warrant chemical consumption. If a product or system warranty is required, please contact your Hydranautics representative. Non-standard or extended warranties may result in different pricing than previously quoted.
(8/63)

Permeate throttling(ALL STAGES) WITH Pressure/Work Exchanger

RO program licensed to:					
Calculation created by:					
Project name:	Carriacou		Permeate flow:	13.00	m3/hr
HP Pump flow:	13.2	m3/hr	Raw water flow:	30.2	m3/hr
			Permeate throttling(All st.)	1.0	bar
Feed pressure:	53.8	bar	Permeate recovery:	43.0	%
Feedwater Temperature:	25.0	C(77F)			
Feed water pH:	8.00		Element age:	2.0	years
Chem dose, ppm (100%):	0.0	H2SO4	Flux decline % per year:	5.0	
			Fouling Factor	0.90	
			Salt passage increase, %/yr:	7.0	
Average flux rate:	10.4	gfd	Feed type:	Seawater-well or MF/UF Pretreatment	

Stage	Perm. Flow m3/hr	Flow/Vessel Feed m3/hr	Flow/Vessel Conc m3/hr	Flux gfd	Beta	Conc.&Throt. Pressures bar	Conc.&Throt. Pressures bar	Element Type	Elem. No.	Array
1-1	13.0	10.1	5.7	10.4	1.01	52.4	1.0	SWC6 MAX	18	3x6

	Raw water	Adjusted Water	Feed water	Permeate	Concentrate	ERD Reject
Ion	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Ca	433.0	433.0	444.7	0.913	779.5	758.9
Mg	1330.0	1330.0	1365.9	2.804	2394.2	2331.0
Na	11086.0	11086.0	11382.7	111.927	19885.2	19362.5
K	398.0	398.0	408.6	5.019	713.1	694.4
NH4	0.0	0.0	0.0	0.000	0.0	0.0
Ba	0.052	0.052	0.053	0.000	0.094	0.1
Sr	0.000	0.000	0.000	0.000	0.000	0.0
CO3	15.9	15.9	16.6	0.000	35.3	34.2
HCO3	146.0	146.0	149.6	2.372	253.3	246.9
SO4	2787.0	2787.0	2862.2	6.323	5016.6	4884.2
Cl	19960.0	19960.0	20494.8	180.774	35819.4	34877.3
F	1.0	1.0	1.0	0.018	1.8	1.7
NO3	0.0	0.0	0.0	0.000	0.0	0.0
B	4.00	4.00	4.07	1.338	6.13	6.0
SiO2	1.0	1.0	1.0	0.01	1.8	1.7
CO2	0.74	0.75	0.75	0.75	0.75	0.75
TDS	36162.0	36161.9	37131.2	311.5	64906.3	63198.9
pH	8.00	8.00	8.00	6.71	7.92	

	Raw water	Feed water	Concentrate
CaSO4 / Ksp * 100:	22%	23%	47%
SrSO4 / Ksp * 100:	0%	0%	0%
BaSO4 / Ksp * 100:	209%	216%	410%
SiO2 saturation:	1%	1%	1%
Langelier Saturation Index	1.16	1.19	1.58
Stiff & Davis Saturation Index	0.21	0.23	0.56
Ionic strength	0.72	0.74	1.29
Osmotic pressure	26.4 bar	27.1 bar	47.4 bar

H.P. Differential of Pressure/Work Exchanger	0.5	bar	Pressure/Work Exchanger Leakage:	1 %
Pressure/Work Exchanger Boost Pressure	1.9	bar	Volumetric Mixing	6 %

Product performance calculations are based on nominal element performance when operated on a feed water of acceptable quality. The results shown on the printouts produced by this program are estimates of product performance. No guarantee of product or system performance is expressed or implied unless provided in a separate warranty statement signed by an authorized Hydranautics representative. Calculations for chemical consumption are provided for convenience and are based on various assumptions concerning water quality and composition. As the actual amount of chemical needed for pH adjustment is feedwater dependent and not membrane dependent, Hydranautics does not warrant chemical consumption. If a product or system warranty is required, please contact your Hydranautics representative. Non-standard or extended warranties may result in different pricing than previously quoted.
(8/63)

Permeate throttling(ALL STAGES) WITH Pressure/Work Exchanger

RO program licensed to:					
Calculation created by:					
Project name:	Carriacou		Permeate flow:	13.00	m3/hr
HP Pump flow:	13.2	m3/hr	Raw water flow:	30.2	m3/hr
			Permeate throttling(All st.)	1.0	bar
Feed pressure:	53.8	bar	Permeate recovery:	43.0	%
Feedwater Temperature:	25.0	C(77F)			
Feed water pH:	8.00		Element age:	2.0	years
Chem dose, ppm (100%):	0.0	H2SO4	Flux decline % per year:	5.0	
			Fouling Factor	0.90	
			Salt passage increase, %/yr:	7.0	
Average flux rate:	10.4	gfd	Feed type:	Seawater-well or MF/UF Pretreatment	

Stage	Perm. Flow m3/hr	Flow/Vessel Feed m3/hr	Flow/Vessel Conc m3/hr	Flux gfd	Beta	Conc.&Throt. Pressures bar	Conc.&Throt. Pressures bar	Element Type	Elem. No.	Array
1-1	13.0	10.1	5.7	10.4	1.01	52.4	1.0	SWC6 MAX	18	3x6

Stg	Elem no.	Feed pres bar	Pres drop bar	Perm flow m3/hr	Perm Flux gfd	Beta	Perm sal TDS	Conc osm pres	Ca	Mg	Cl	B	SiO2
									Cumulative Perm Ion levels				
1-1	1	53.8	0.3	1.5	20.9	1.06	118.6	31.7	0.36	1.11	67	0.56	0.00
1-1	2	53.5	0.3	1.1	15.4	1.04	146.4	36.1	0.45	1.37	82	0.68	0.00
1-1	3	53.2	0.2	0.8	10.9	1.03	179.3	40.1	0.55	1.68	101	0.82	0.00
1-1	4	53.0	0.2	0.5	7.2	1.03	219.2	43.3	0.67	2.05	123	0.98	0.00
1-1	5	52.8	0.2	0.3	4.8	1.02	263.3	45.6	0.80	2.46	147	1.15	0.01
1-1	6	52.6	0.2	0.2	3.2	1.02	310.3	47.4	0.95	2.90	174	1.34	0.01

Stage	NDP bar
1-1	15.2

Product performance calculations are based on nominal element performance when operated on a feed water of acceptable quality. The results shown on the printouts produced by this program are estimates of product performance. No guarantee of product or system performance is expressed or implied unless provided in a separate warranty statement signed by an authorized Hydranautics representative. Calculations for chemical consumption are provided for convenience and are based on various assumptions concerning water quality and composition. As the actual amount of chemical needed for pH adjustment is feedwater dependent and not membrane dependent, Hydranautics does not warrant chemical consumption. If a product or system warranty is required, please contact your Hydranautics representative. Non-standard or extended warranties may result in different pricing than previously quoted.

Permeate throttling(ALL STAGES) WITH Pressure/Work Exchanger

RO program licensed to:				
Calculation created by:				
Project name:	Carriacou		Permeate flow:	13.00 m3/hr
HP Pump flow:	13.2 m3/hr		Raw water flow:	30.2 m3/hr
			Permeate throttling(All st.)	1.0 bar
Feed pressure:	54.3 bar		Permeate recovery:	43.0 %
Feedwater Temperature:	25.0 C(77F)			
Feed water pH:	8.00		Element age:	3.0 years
Chem dose, ppm (100%):	0.0 H2SO4		Flux decline % per year:	5.0
			Fouling Factor	0.86
			Salt passage increase, %/yr:	7.0
Average flux rate:	10.4 gfd		Feed type:	Seawater-well or MF/UF Pretreatment

Stage	Perm. Flow m3/hr	Flow/Vessel Feed m3/hr	Conc m3/hr	Flux gfd	Beta	Conc.&Throt. Pressures bar	bar	Element Type	Elem. No.	Array
1-1	13.0	10.1	5.7	10.4	1.01	52.9	1.0	SWC6 MAX	18	3x6

Ion	Raw water mg/l	Adjusted Water mg/l	Feed water mg/l	Permeate mg/l	Concentrate mg/l	ERD Reject mg/l
Ca	433.0	433.0	444.7	0.966	779.4	758.8
Mg	1330.0	1330.0	1365.9	2.966	2394.0	2330.8
Na	11086.0	11086.0	11382.5	118.353	19880.1	19357.7
K	398.0	398.0	408.6	5.307	712.9	694.2
NH4	0.0	0.0	0.0	0.000	0.0	0.0
Ba	0.052	0.052	0.053	0.000	0.094	0.1
Sr	0.000	0.000	0.000	0.000	0.000	0.0
CO3	15.9	15.9	16.6	0.000	35.3	34.2
HCO3	146.0	146.0	149.6	2.507	253.2	246.9
SO4	2787.0	2787.0	2862.2	6.686	5016.3	4883.9
Cl	19960.0	19960.0	20494.5	191.153	35811.0	34869.5
F	1.0	1.0	1.0	0.019	1.8	1.7
NO3	0.0	0.0	0.0	0.000	0.0	0.0
B	4.00	4.00	4.07	1.407	6.08	6.0
SiO2	1.0	1.0	1.0	0.01	1.8	1.7
CO2	0.74	0.75	0.75	0.75	0.75	0.75
TDS	36162.0	36161.9	37130.8	329.4	64892.0	63185.4
pH	8.00	8.00	8.00	6.73	7.92	

	Raw water	Feed water	Concentrate
CaSO4 / Ksp * 100:	22%	23%	47%
SrSO4 / Ksp * 100:	0%	0%	0%
BaSO4 / Ksp * 100:	209%	216%	410%
SiO2 saturation:	1%	1%	1%
Langelier Saturation Index	1.16	1.19	1.58
Stiff & Davis Saturation Index	0.21	0.23	0.56
Ionic strength	0.72	0.74	1.29
Osmotic pressure	26.4 bar	27.1 bar	47.4 bar

H.P. Differential of Pressure/Work Exchanger	0.5 bar	Pressure/Work Exchanger Leakage:	1 %
Pressure/Work Exchanger Boost Pressure	1.9 bar	Volumetric Mixing	6 %

Product performance calculations are based on nominal element performance when operated on a feed water of acceptable quality. The results shown on the printouts produced by this program are estimates of product performance. No guarantee of product or system performance is expressed or implied unless provided in a separate warranty statement signed by an authorized Hydranautics representative. Calculations for chemical consumption are provided for convenience and are based on various assumptions concerning water quality and composition. As the actual amount of chemical needed for pH adjustment is feedwater dependent and not membrane dependent, Hydranautics does not warrant chemical consumption. If a product or system warranty is required, please contact your Hydranautics representative. Non-standard or extended warranties may result in different pricing than previously quoted.
(8/63)

Permeate throttling(ALL STAGES) WITH Pressure/Work Exchanger

RO program licensed to:					
Calculation created by:					
Project name:	Carriacou		Permeate flow:	13.00	m3/hr
HP Pump flow:	13.2	m3/hr	Raw water flow:	30.2	m3/hr
			Permeate throttling(All st.)	1.0	bar
Feed pressure:	54.3	bar	Permeate recovery:	43.0	%
Feedwater Temperature:	25.0	C(77F)			
Feed water pH:	8.00		Element age:	3.0	years
Chem dose, ppm (100%):	0.0	H2SO4	Flux decline % per year:	5.0	
			Fouling Factor	0.86	
			Salt passage increase, %/yr:	7.0	
Average flux rate:	10.4	gfd	Feed type:	Seawater-well or MF/UF Pretreatment	

Stage	Perm. Flow m3/hr	Flow/Vessel Feed m3/hr	Flow/Vessel Conc m3/hr	Flux gfd	Beta	Conc.&Throt. Pressures bar	Conc.&Throt. Pressures bar	Element Type	Elem. No.	Array
1-1	13.0	10.1	5.7	10.4	1.01	52.9	1.0	SWC6 MAX	18	3x6

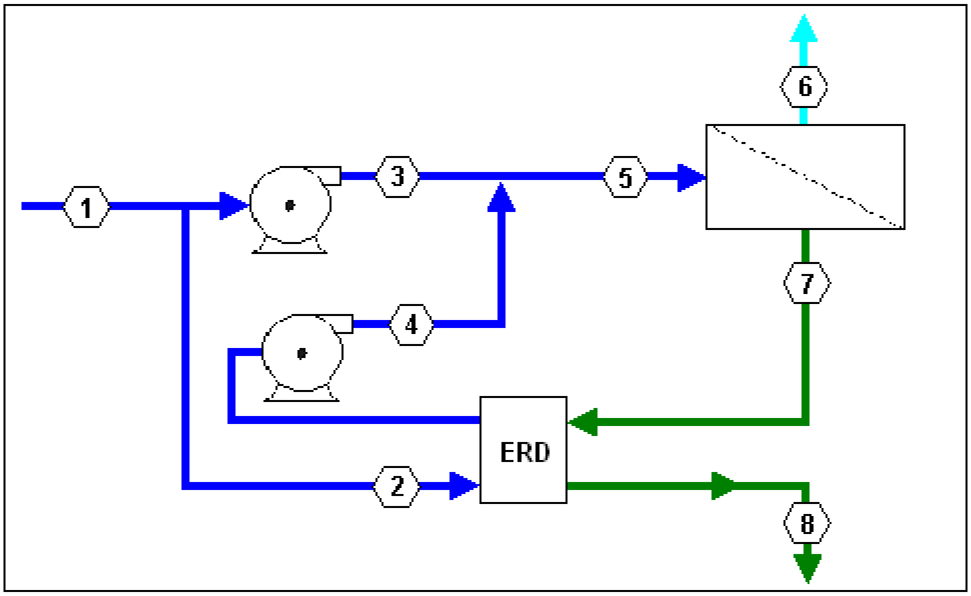
Stg	Elem no.	Feed pres bar	Pres drop bar	Perm flow m3/hr	Perm Flux gfd	Beta	Perm sal TDS	Conc osm pres	Ca	Mg	Cl	B	SiO2
									Cumulative Perm Ion levels				
1-1	1	54.3	0.3	1.4	20.4	1.05	128.6	31.5	0.39	1.21	72	0.61	0.00
1-1	2	54.0	0.3	1.1	15.3	1.04	157.6	35.9	0.48	1.48	88	0.73	0.00
1-1	3	53.7	0.2	0.8	11.0	1.03	191.8	39.9	0.58	1.79	108	0.87	0.00
1-1	4	53.4	0.2	0.5	7.4	1.03	233.3	43.1	0.71	2.18	131	1.04	0.01
1-1	5	53.2	0.2	0.3	5.0	1.02	279.1	45.5	0.85	2.61	156	1.22	0.01
1-1	6	53.0	0.2	0.2	3.4	1.02	328.0	47.4	1.00	3.07	184	1.41	0.01

Stage	NDP bar
1-1	15.7

Product performance calculations are based on nominal element performance when operated on a feed water of acceptable quality. The results shown on the printouts produced by this program are estimates of product performance. No guarantee of product or system performance is expressed or implied unless provided in a separate warranty statement signed by an authorized Hydranautics representative. Calculations for chemical consumption are provided for convenience and are based on various assumptions concerning water quality and composition. As the actual amount of chemical needed for pH adjustment is feedwater dependent and not membrane dependent, Hydranautics does not warrant chemical consumption. If a product or system warranty is required, please contact your Hydranautics representative. Non-standard or extended warranties may result in different pricing than previously quoted.
(8/63)

Carriacou **10/10/14**

SINGLE STAGE SYSTEM, PERMEATE THROTTLING(ALL STAGES) WITH Pressure/Work



		1	2	3	4	5	6	7	8
Flow	m3/hr	30.2	17.0	13.2	17.0	30.2	13.0	17.2	17.2
Pressure	bar	0.0	0.0	54.3	54.3	54.3	1.0	52.9	0.0
TDS (ppm)		36162.0	36161.9	36161.9	37885.8	37130.8	329.4	64892.0	63185.4

Water Equipment Technologies
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Appendix C

INSTALLATION, OPERATION, & MAINTENANCE MANUAL

PX-Series (25-120 gpm units)

INSTALLATION, OPERATION, & MAINTENANCE MANUAL

PX-Series (25-120 gpm units)

Energy Recovery Pressure Exchanger

Energy Recovery, Inc.
1908 Doolittle Drive, San Leandro, CA 94577 USA
Tel: +1 510 483 7370 / Fax: +1 510 483 7371
www.energy-recovery.com / sales@energy-recovery.com
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Note: Read entire manual before installing or operating the equipment.

6-03 Rev J

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1.0 INTRODUCTION

This manual contains instructions for the installation, operation, and maintenance of your Pressure Exchanger (PX) for Sea Water Reverse Osmosis (SWRO) energy recovery. This information is provided to ensure the long life and safe operation of your Pressure Exchanger system, therefore please read this manual thoroughly before installation or 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

This Pressure Exchanger has been designed to provide safe and reliable service. However, it is both a pressure housing and a piece of rotating machinery and it is designed to operate at high pressure, which requires special consideration. Therefore, the operator(s) must exercise good judgment and proper safety practices to avoid damage to the equipment, surrounding areas and to prevent personal 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 and proper shutdown devices and over-pressure protection equipment should be an essential part of any such program. In general, all personnel should be guided by all the basic rules of safety associated with high pressure equipment and the process.

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 4-2, or used with liquids not previously approved.

Operation under conditions outside of those stated in Table 4.2 can result in damage to the Pressure Exchanger and will void the warranty

2.1 Warning, Caution & Note Tags

The following are definitions of the types of flags used in this manual. They should be given special attention when they appear in the text.

WARNING!

These flags denote items if not strictly observed, can result in **serious injury to personnel**.

CAUTION

These flags denote items if not strictly observed, can result in **damage or destruction to equipment**.

Note

These flags denote items that need highlighting.

3.0 QUALITY & ARRIVAL INSPECTION

ERI's commitment to quality starts with top quality materials, machined to extreme tolerances. Every part is checked to insure it meets all dimensional specifications during and after each stage of the fabrication process, and following assembly. Pressure Exchanger (PX) units are subjected to extensive testing in our wet test facility. Measurements are recorded of noise levels, pressures and flow rates. Each unit is given a serial number and the test reports are filed at ERI and copies are sent with each unit.

Each unit should be inspected immediately upon arrival and any irregularities due to shipment should be reported to the carrier. The PX has been packed with plugs in the fittings and wrapped in a plastic bag to keep it wet and free of debris. The PX has been run with a 0.25% solution of Sodium Metabisulfite ($NaHSO_2$) to minimize the possibility of biological growth due to exposure to contaminants during shipment and storage. Care must be taken during unpacking and handling to avoid damage to the PX.

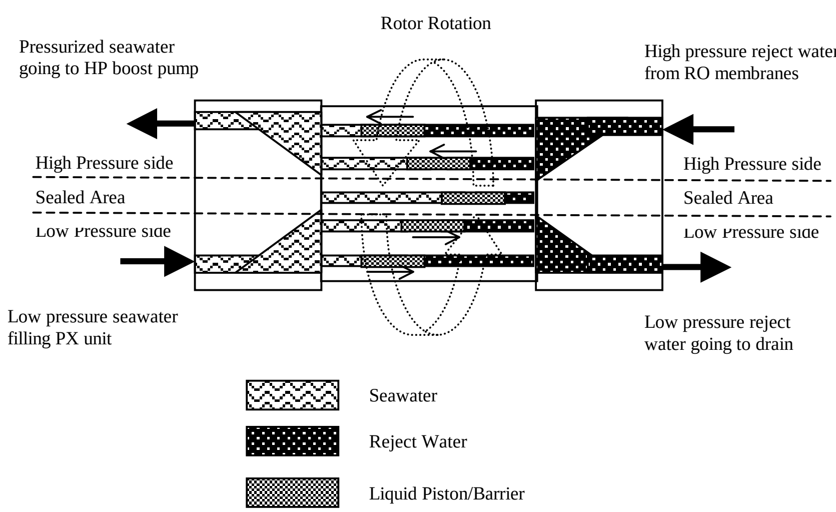
When handling and installing the PX care should be taken not to drop the unit or put undue strain on the end pipe connections as internal damage may occur.

4.0 PRINCIPLE OF OPERATION

The PX unit utilizes the principle of positive displacement to allow low-pressure filtered and/or treated seawater to be pressurized by direct contact with the concentrated brine stream from a seawater reverse osmosis system. The device uses a cylindrical rotor with longitudinal ducts to transfer the pressure energy from the concentrate/reject stream to the feed stream. The rotor spins inside a sleeve between two end covers with port openings for low and high pressure. The low-pressure side of the rotor fills with seawater and the high-pressure side discharges seawater.

By rotation the ducts are exposed to the low pressure feed water, which fills the duct and displaces the reject water. The rotor continues to rotate and is exposed to the high-pressure concentrate, which fills the duct and displaces the feed water at high pressure. The ducts are continuously filling and discharging with the rotation of the rotor. At 1500 rpm one revolution is completed every 1/25 second. See Figure 4-1 below.

Figure 4-1. Pressure Exchanger Flow Path



Applying PX Pressure Exchanger technology to SWRO is different from conventional recovery device system design, but in practice is quite simple. The reject brine from the SWRO membranes (G) is passed through the PX unit, where its pressure energy is transferred directly to a portion of the incoming raw seawater at up to 95% efficiency. This seawater stream (D), nearly equal in volume and pressure to the reject stream, then passes through the PX booster pump, not the main high-pressure pump. This point is significant**, because now the main pump is sized to match the permeate flow, not the full feed flow**. In a typical SWRO plant using the PX system, the main pump will provide 41% of the energy, the booster will provide 2% and the PX will provide the remaining 57%. Since the PX uses no external power, the **total power saving is 57%,** compared to a system with no recovery.

It is also important to note from Figure 4-1 above that the high pressure side of the PX and its associated flow rate are disconnected from the low pressure side of the PX and its associated flow rate. **There is no physical connection between the flow rate on the high pressure side and the flow rate on the low pressure side of the PX. Therefore, in order for the equipment to work properly, the desalination plant operator must balance these flow rates by using flow meters and controls.**

The simple flow diagram below shows of a typical PX Pressure Exchanger installed in an RO system.

Figure 4-2. Typical System Flow Path

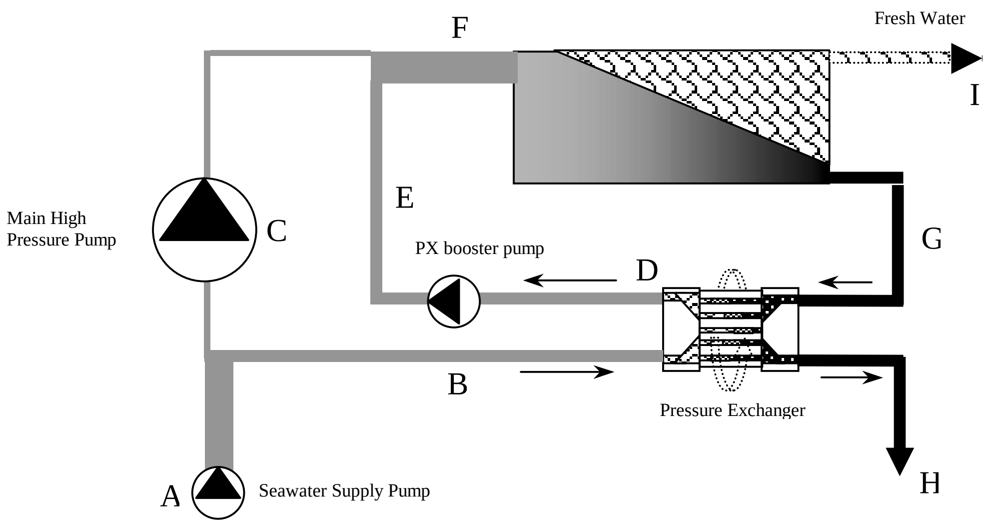


Table 1. Example Flow Rates and Pressures

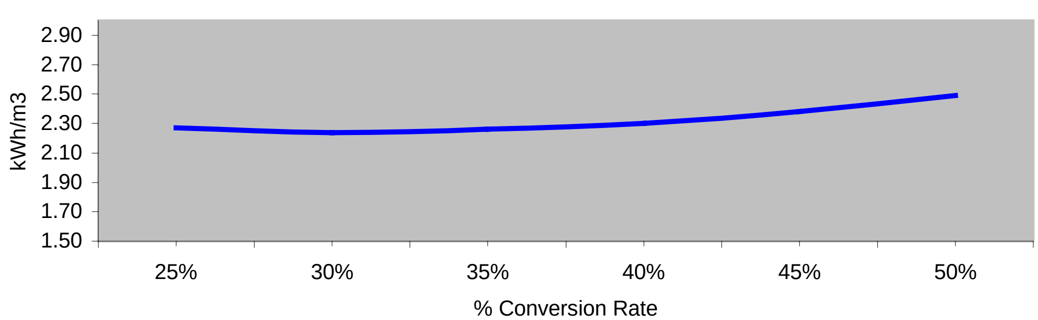
STREAM	DESCRIPTION	FLOW RATE*	PRESS. PSI/BAR
A	Seawater supply	100	29 / 2
B	PX LP Inlet/ Seawater	58.8	29 / 2
C	Main HP Pump outlet	41.2	1000 / 69
D	PX HP Outlet/ Seawater	58.8	957 / 66
E	Booster Pump Outlet/ Seawater	58.8	1000 / 69
F	RO Feed Stream	100	1000 / 69
G	PX HP Inlet/ Reject	60.0	971 / 67
H	PX LP Outlet/ Reject	60.0	15 / 1
I	RO Product Water	40.0	5 / 0.3

*40% conversion rate RO system independent of units.

It is important to note that the PX and associated boost pump are handling nearly 100% of the reject flow. The role and size of the main high-pressure pump has been reduced to that of a "make up pump" to compensate for the water that is exiting the RO system as permeate. Product water flow (I) and reject flow are being provided by two independent pumping systems and therefore are <u>unrelated to one another.</u>

Since the PX equipment is exchanging the reject flow with a nearly equal volume of fresh seawater, and since this exchange takes place at over 95% efficiency, there is very little energy penalty associated with increasing this flow and thereby lowering the recovery rate of the RO system. At lower recoveries the operating pressure required to produce a given amount of product water is reduced substantially. Since the main high-pressure pump flow equals the product water flow PX technology therefore makes possible lower energy consumption at low recovery rates. The overall energy consumption of an SWRO plant using the PX device has a low point at RO recovery rates typically between 30-40%. Outside this recovery range, the plant will start to consume slightly higher amounts of power.

Figure 4-3 kWh/m3 Vs Recovery Rate
SWRO at 36,000 TDS feed water @ 25C and 12 GFD



It should also be noticed from figure 4-2 above that the rate of flow of the high pressure stream through the PX (D and G) is being driven by the PX booster pump. The booster pump pushes a portion of the feed flow (D), equal to the reject flow through the RO membranes, out the high pressure reject of the membranes (G), through the Pressure Exchanger (where it is exchanged for new feed water), and back into the PX booster pump**. Because of the exchange process inherent in the PX, this flow rate is in no way connected to, and cannot be determined by measuring any of the flow rates on the low-pressure side of the PX (B and H).** The simplest and most practical way to determine these high pressure flow rates is by incorporating a high-pressure flow meter into the PX high-pressure system loop (D or G).

4.1 Specifications

4.1.1 PX Performance Characteristics

Table 4.2 System Performance Specifications

Parameter	Specification	
	English Units	SI
Seawater temperature range, F°/C°	33-110	1-45
Minimum seawater inlet pressure (LP IN)	30 psi	2.0Bar
Maximum seawater inlet pressure (LP IN)	100 psi	6.9Bar
Minimum reject water inlet pressure (HP IN)	N/A	N/A
Maximum reject water inlet pressure (HP IN)	1200 psi	82.74Bar
Minimum seawater outlet pressure (HP OUT)	N/A	N/A
Maximum seawater outlet pressure (HP OUT)	N/A	N/A
Minimum reject water discharge pressure (LP OUT)	5 psi (1)	0.34Bar
Maximum reject water discharge pressure (LP OUT)	75 psi	5.2Bar
Minimum nominal filtration requirement	5 micron	
pH range	1-12 (short term at limits)	
Allowable flow rates	gpm	m^3/hr
PX-15	10-15	2.3-3.4
PX-25	16-25	3.6-5.7
PX-40	26-40	5.9-9.1
PX-60	41-60	9.3-13.6
PX-90	61-90	13.9-20.4
PX-120	91-120	20.7-27.3

(1) The PX can operate at discharge to atmosphere but will have an increased noise profile.
(2) Up to a 25 psi differential pressure should be maintained across the low pressure side of the PX to achieve maximum rated flow.
(3) Unlimited system capacities are achieved by arranging units together in parallel.

WARNING!

Do not allow the high-pressure reject and/or seawater to exceed 1200 psi. If necessary, install a pressure switch and/or safety valve in the high-pressure line(s) to ensure the system does not exceed 1200 psi.

CAUTION

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

5.0 INSTALLATION

The Pressure Exchanger has four connections labeled HP IN, HP OUT, LP IN, and LP OUT.

- 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 high-pressure connections on the Pressure Exchanger are made of 254 SMO® stainless steel or equivalent. The low-pressure connections are made of schedule 120 PVC pipe (some models have threaded connections in the PVC base for low pressure piping connections). Proper piping design and piping support design must be used in order to minimize external stresses on all piping connections. **The Pressure Exchanger must not be supported by its piping connections, nor should the Pressure Exchanger be allowed to support piping or manifolds.** A pressure gage should be installed near each pipe connection of the PX to permit monitoring of PX performance.

CAUTION

Thoroughly flush associated piping with water filtered to 5 microns before installing the PX. Foreign material will cause the rotor to seize.

Victaulic style pipe joints are standard. Use only water-soluble lubricants such as glycerin or soap on all o-rings and seals. Do not use grease.

CAUTION

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

The Pressure Exchanger can be mounted in any orientation, however, the PX 15-60 are intended to be mounted vertically on their bases. Bearing pads should be used to avoid abrasion of the vessel. See Section 13 for dimensioned drawings and Process and Instrumentation Diagrams.

6.0 OPERATION

The successful use of the PX depends on observing some basic operating conditions and precautions. The PX unit must be installed, operated and maintained in accordance with the precautions listed 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.

The following precautions / conditions apply:

- Piping connections to the Pressure Exchanger must be designed so as not to induce stress on the Pressure Exchanger foundation or pressure vessel.
- The high-pressure access covers incorporate interlocking restraining devices which must be kept dry and free of corrosion. Deterioration of these devices could lead to catastrophic mechanical failure of the pressure vessel.
- Seawater feed to the Pressure Exchanger must go through the same pretreatment as seawater being fed to the membranes and must be filtered to at least 5 microns.
- Under no circumstances shall the brine inlet pressure pressure exceed 1200 psig.
- Under no circumstances shall the seawater feed inlet pressure exceed 100 psig. The minimum pressure shall be 30 psig.
- The Pressure Exchanger must be removed from the system when performing hydrostatic testing on piping or other system components. Never attempt to hydrostatically test the Pressure Exchanger.

6.1 START AND STOP PROCEDURES

6.1.1 System start up sequence:

1. All valves should be in their normal operating positions.
2. Start the sea water inlet supply pump (all valves positioned for normal system operation.) The feed flow through the Pressure Exchanger may cause the rotor to begin to rotate. This rotation will be confirmed by a slight humming noise.

3. Bleed air from the system.
4. Start the PX booster pump. Rotor speed will increase and remaining air will be released from the Pressure Exchanger and membrane modules.
5. Start the main high pressure pump. System pressure will increase to the point where the permeate flow will equal the flow from the high pressure pump. Noise level from the Pressure Exchanger will increase. Small variations in noise level and rotor speed are normal. Check rotors to insure they are all rotating.

Note

After starting the main high-pressure pump the system will pressurize in a relatively short period of time (5-10 seconds). If a slower pressurization cycle 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 control the pressurization cycle time.

6.1.2 short term (1-3 days) System shut down sequence:

1 Stop the high-pressure pump.
2 Wait until the system pressure drops below 400 psi.
3 Stop the PX booster pump.
4 Stop the seawater inlet supply pump.

WARNING!

The RO system will remain pressurized (>200psi) for up to 40 minutes after shutdown. Verify that all of the pressure has been de-energized from the system before performing maintenance.

Note

If a more rapid de-pressurization cycle 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 from the RO membranes.

6.1.3 Medium Term (1-2 weeks) System shut down sequence:

1. Feed the PX and SWRO system with fresh water and make sure booster pump is operating as this expedites the flushing cycle. Fresh water flush inhibits biological growth

Note

A minimum of 25 psi is required to feed the PX low-pressure inlet. The fresh water flush will not occur without sufficient pressure.

Note

It is not recommended to operate the main high pressure pump during this sequence however momentary operation is recommend to purge it of standing seawater.

CAUTION

Failing to fresh water flush the Pressure Exchanger **will void the warranty** and may result in excessive biological growth that may foul the rotor and inhibit rotation upon start-up.

2. Stop the PX booster pump.

3. Isolate the fresh water supply source.

6.1.4 long term (over 2 weeks System shut down sequence:

1. If a plant is to be shut down for an extended period of time, the RO system including the Pressure Exchangers must be thoroughly flushed with fresh water to remove any salt, and precautions should

be taken to inhibit biological growth. The Pressure Exchangers should be finally flushed with the same solution used in preserving the RO membranes.

CAUTION

Failing to fresh water flush and properly preserve the pressure exchanger **will void the warranty** and may result in excessive biological growth that may foul the rotor and inhibit rotation upon start-up.

6.2 FLOW CONTROL AND BALANCING THE SYSTEM

Refer to Process and Instrumentation Diagram (P&ID) in section 13.0. Flow rates and pressures in a typical SWRO plant will vary slightly over the life of a plant due to temperature, membrane fouling, or feed salinity variations. The Pressure Exchanger rotor is powered by the flow of fluids through the unit and the speed of the rotor is self-adjusting over the PX's operating range. The following equations apply to a properly installed Pressure Exchanger system and can be used in determining the flow rates in and out of that system:

HP concentrate inlet flow = HP seawater outlet flow + Bearing lubrication flow (EQ1)

LP seawater inlet flow = LP reject water outlet - Bearing lubrication flow (EQ2)

Bearing lubrication flow approximately equals # of PX rotors * 1 gpm (EQ3)

Note: PX 25-60 uses one rotor and PX 90-120 uses two rotors.

6.2.1 High Pressure Reject and Seawater Feed Flow Control

To control the flow rates of the high pressure seawater outlet (HP OUT) and high pressure reject inlet (HP IN), adjustment of the pressure and flow supplied by the PX booster pump (P1) are typically required. 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. The flow and pressure of this booster pump is then controlled with a variable frequency drive or control valve (V2**).**

WARNING!

<u>The High Pressure flow through the PX unit must never exceed the maximum rated flow. The only positive way to determine this flow is to use a high-pressure flow meter (FI3) to measure the amount of water flowing through the high-pressure side of the Pressure Exchanger device.</u>

HP reject inlet flow equals the HP seawater outlet flow plus a small amount of water dedicated to lubricate the hydrodynamic bearing (see EQ1).

6.2.2 Low Pressure Reject and Seawater Flow Control

To control flow rates of the low-pressure seawater inlet (LP IN) and low pressure reject flow outlet (LP OUT), adjustments to the low-pressure reject outlet pressure should be made. Recommended practice is to install a valve (V8) at the low-pressure reject outlet of the PX unit(s).

WARNING!

<u>The Low Pressure flow through the PX unit must never exceed the maximum rated flow. The only positive way to determine this flow is to use a low pressure flow meter (FI2) in the low-pressure seawater inlet line.</u>

Low-pressure seawater inlet flow equals the low pressure reject water outlet flow minus a small amount of water coming from the hydrodynamic bearing (see EQ2).

6.2.3 Balancing the Pressure Exchanger using flow meters

All flows in and out of the Pressure Exchanger should be balanced to within 5.0% for optimum SWRO operation. The preferred method of achieving this is with the use of flow meters installed on the low-pressure seawater inlet and high-pressure seawater outlet.

CAUTION

Operating the Pressure Exchanger in a grossly unbalanced condition may result in failure of the hydrodynamic bearing and will void the warranty.

The following equation is the goal of this process:

HP seawater outlet flow = LP seawater inlet flow (EQ4) (see note below)

Note

Because there is no physical connection between the flow rate on the high-pressure side and the flow rate on the low-pressure side of the PX, this equation applies to a system in which the operator has properly balanced these flow rates through the use of the recommended flow meters and controls.

1. Determine the desired amount of the PX high-pressure seawater outlet flow for your system. Adjust the variable frequency drive on the PX booster pump (P1) or control valve (V2) until that flow rate is achieved as seen at the high-pressure flow meter (FI3).
2. Adjust the low-pressure reject water outlet flow valve (V8) until the low-pressure seawater inlet flow (FI2) equals the high-pressure seawater outlet flow (FI3).

If the low pressure seawater inlet flow is less than the high pressure seawater outlet flow excessive intermixing of concentrate with the feed will occur which will result in lower quality permeate, increased feed pressure and higher energy consumption. If the low-pressure seawater inlet flow is greater than the high-pressure seawater outlet flow, treated feed water is being wasted and dumped to the low-pressure reject drain.

6.2.4 Verification of the PX System Balance Using a Salinity Meter and low pressure flow meter

*See Section 9.1 for contact information.

Once the PX has been balanced using flow meters, the system balance set points can be verified by checking conductivity through the following iterative method.

1. Determine the desired amount of the PX high-pressure seawater outlet flow for your system. Adjust the variable frequency drive on the PX booster pump (P1) or control valve (V2) until that flow rate is achieved as seen at the high-pressure flow meter (FI3).
2. Adjust the low-pressure reject water outlet flow valve (V8) until the low-pressure seawater inlet flow (FI2) equals the high-pressure seawater outlet flow (FI3).
3. Begin slowing down the flow rate through the high-pressure side of the PX by lowering the setting on the PX booster pump VFD or closing the control valve (V2). At each flow increment take a salinity sample from the high-pressure outlet of the PX. Remember to wait a sufficient amount of time (10-20 minutes) for the salinity in the system to stabilize between iterations. When the high pressure flow rate is significantly greater than the low pressure flow rate, the salinity at the PX high pressure outlet will be excessively high due to the "blow through" of reject water inside the PX. As the high pressure flow rate is decreased and begins to balance/match the low pressure flow rate of the PX, the salinity at the PX high pressure outlet should drop to within 3-4% of the salinity at the low pressure seawater inlet flow rate.

6.2.5 Verification That Each Rotor is Balanced and Spinning

A sample connection at the low pressure outlet of each PX can be used to determine if both rotors in a single PX assembly are operating correctly. The advantages of using the LP outlet is that it avoids high-pressure sample connections and can employ a low cost, corrosion resistant plastic valve. When the PX rotors are operating normally and balanced flow is achieved the low pressure outlet water will have salinity equal to the reject water from the membranes. When one or more rotors is not functioning properly the salinity will go in the direction of pure seawater. This sample point can be particularly valuable in multiple PX installations where the failure of one rotor would produce non-detectable results to the overall outlet salinity of the multiple units combined.

A ¼" FNPT (plugged) sample connection has also been provided at each PX end cap. This point is directly connected to the high-pressure seawater outlet of each individual rotor. It can be used to determine if an individual rotor is receiving balanced flow and/or spinning correctly. When a rotor stops spinning the high-pressure outlet flow salinity will be equal to the high-pressure inlet reject salinity.

7.0 MAINTENANCE INSTRUCTIONS

7.1 GENERAL

The table below details the specific recommended PX maintenance requirements for the ERI's PX units:

	Weekly	3 Months	As Required	Labor Hours (approximate)
Inspect connections	•			0.1
Inspect internal assembly			•	2.0

Table 7.0 - Maintenance Task Chart

CAUTION

Introduction of non-water soluble films such as grease, oil, wax, etc can cause the Pressure Exchanger to stick and stop rotating. Only ERI approved lubricants, cleaners and o-ring gels should be used in PX maintenance and with the PX Booster Pumps.

Once the inlet and outlet operating flows of the PX have been measured and balanced properly and if proper care is taken to flush the unit after every shut down, the PX system should operate trouble free. The PX Pressure Exchanger needs no scheduled maintenance. There are no shafts, couplings, seals or lubrication system to maintain or monitor. If a plant is to be shut down for an extended period of time, the system, including the Pressure Exchangers should be thoroughly flushed with fresh water to remove any salt, and precautions should be taken to prohibit biological growth. Biological protection should include flushing with Sodium Metabisulfite ($NaHSO_2$), similar to the RO membranes. Introduction of trash or debris into the Pressure Exchanger can cause the rotor to stop and damage could occur. Piping systems must be thoroughly flushed to remove any trash or debris prior to allowing water to flow into the Pressure Exchanger. Damage due to debris in the fluid streams is not covered under warranty.

Note

A sample operating log has been provided below and must be submitted by fax or e-mail to Energy Recovery in San Leandro upon completion of the startup and balancing routines. Submittal of this form with the initial startup data within 24 hours of startup is a condition of obtaining PX warranty coverage. The data must be recorded daily and maintained during the life of the warranty in order to support any claims.

CAUTION

Introduction of non-water soluble films such as grease, oil, wax, etc will cause rotor to stick and stop moving.

Figure 7-1 Sample Operating Log

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

Total # of Pressure Exchangers in Parallel_______________

Model of Pressure Exchanger(s) installed________________

Serial # of Pressure Exchanger(s) installed_______________

Please circle one PSI/GPM _____ Bar/M3/hr___________

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

(Initial data Must be submitted within 24 hours of startup.
Daily data is Required to support any Warranty Claims)

8.0 DISSASSEMBLY AND REPAIR

It is important to note, the type of problem observed to determine how far you must go in the disassembly process. Total disassembly of the PX may not always be necessary. See the trouble shooting section for assistance in diagnosing PX abnormalities. Feel free to contact ERI before beginning any type of PX disassembly.

8.1 Disassembly and Repair of PX 15-60

The PX 15-60 units house one rotor and have 4 separate connections. The model number of your unit should appear on the outside of the vessel. Looking at the assembly drawings at the back of the manual should also help to determine which PX unit you have.

8.1.1 Access Cover Removal and Rotor Inspection

This section describes how to access the PX cartridge to inspect for abnormalities, remove foreign material, and or to aid in evaluating the type of problem you are encountering. See assembly drawings at back of manual for descriptions and exploded views of PX parts and assemblies.

1. Remove 6 each cap screws.

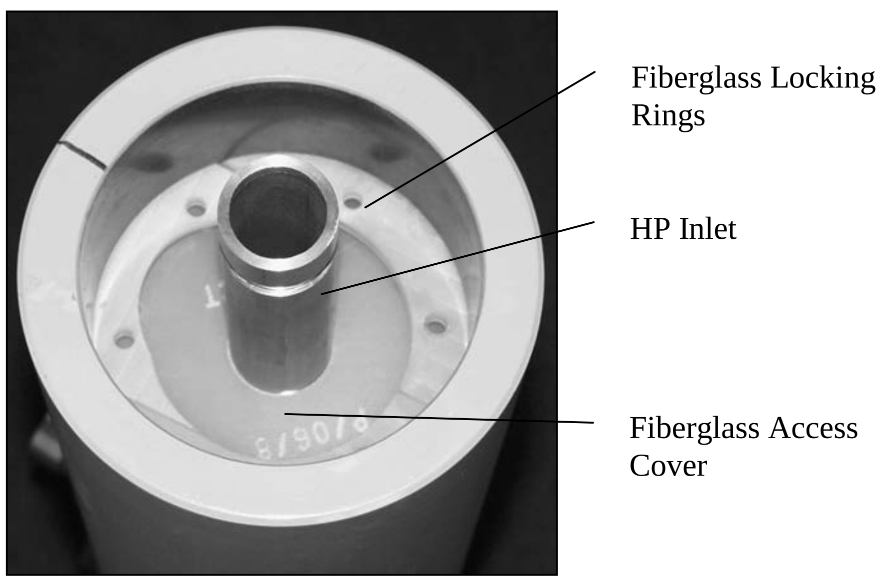


Figure 8-1 PX 15-60 End Cover Assembly

2. Remove fiberglass-locking rings by sliding them out of the vessel groove. After pressurizing the vessel the rings may be locked in place. If necessary, simply tap down on the fiberglass access cover to relieve the pressure on the rings and remove.

3. Remove the Access Cover by placing a coupling on the HP port fitting and using a pry-bar to pull off the access cover.

Note

Apply a liquid soap or any water-soluble lubricant to the ID of the vessel before attempting to remove the access cover.

Use locking ring to protect vessel.

Figure 8-2 Remove Access Cover Position I

Figure 8-3 Remove Access Cover Position II

4. At this point you can easily access and see the rotor. Using a wooden dowel rod, spin the rotor and ensure that it rotates freely. Remove any foreign material that may be surrounding the cartridge. Thoroughly flush the unit with clean fresh water to free the rotors of any particulate matter that may have been lodged between the ceramic pieces.

Exposed Rotor and PX HP Rotor Inlet

Attach lifting ring/bolt. 3/8” x 16 UNC

Figure 8-4 Internal Cartridge and Rotor

Using a flash light and wooden dowel check the following:

A. Rotor is free and clear and can rotate easily.
B. Rotor duct walls have not been chipped and or broken.
C. Foreign debris and material has been removed from all components.
D. All o-rings are in good condition.
E. Check Access Cover for damage.

Note

If rotor does not rotate or there is visible damage to the duct walls or other ceramic components proceed to the cartridge disassembly procedure.

5. After all parts have been inspected and everything appears to be in good working condition the unit should be reassembled and tested in the system. To reassembly the vessel repeat steps 1 through 3 in reverse order.

Note

Use of sufficient lubrication on all o-rings and tight surfaces during the reassembly process is recommended. Liquid soap or any water-soluble lubricant is recommended.

8.1.2 Cartridge Disassembly

This section describes the complete tear down and repair of the PX Ceramic Cartridge. The cartridge should be disassembled only if problems persist or damaged ceramics have been observed. See assembly drawings at back of manual for descriptions and exploded views of PX parts and assemblies.

Note

Care should be taken when handling all of the ceramic parts. There are extremely close tolerance fits and a clean work environment is essential.

1. Mark the ceramic cartridge orientation inside the vessel and note that the cartridge HP inlet hole is on the same side as the HP outlet port.

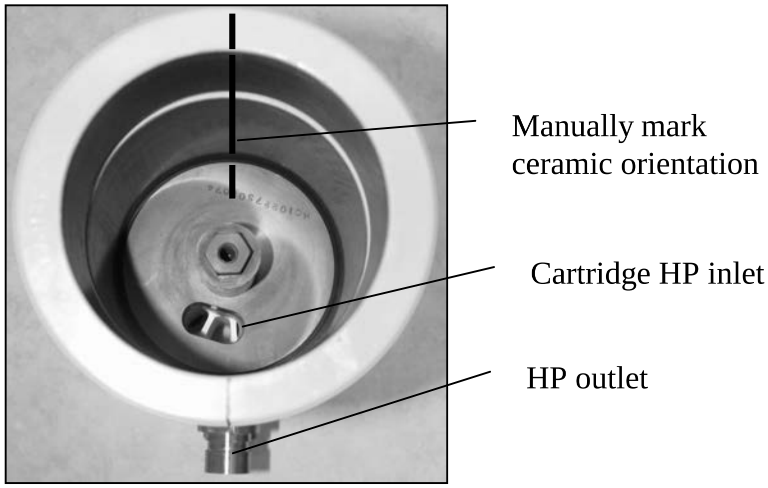


Figure 8-5 PX 15-60 Cartridge Orientation HP

2. Attached a hook or bolt to the 3/8" x 16 UNC female thread at the top of the cartridge tension nut. See Figure 8-4.
3. Pull the PX cartridge out of the vessel using a leaver or puller mechanism.
4. Remove fiberglass glue band with a blade or flat head screwdriver. It should peel off. It is not important to save or reapply the bands. They are used to maintain alignment during shipping only.

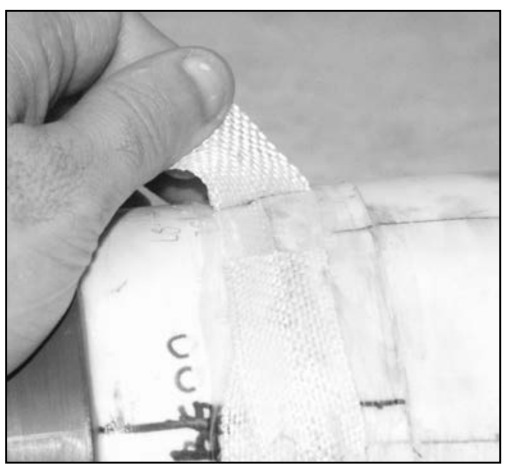


Figure 8-6 Remove Fiber Glass Tape

Note

Some Pressure Exchangers use pins to keep the endcap and sleeves aligned during shipping and reassembly.

5. After the tape has been removed mark the ceramics for easy reassembly. Mark the ceramics 1-4 and with a vertical line to ensure the ceramics are later reassembled in the same position.

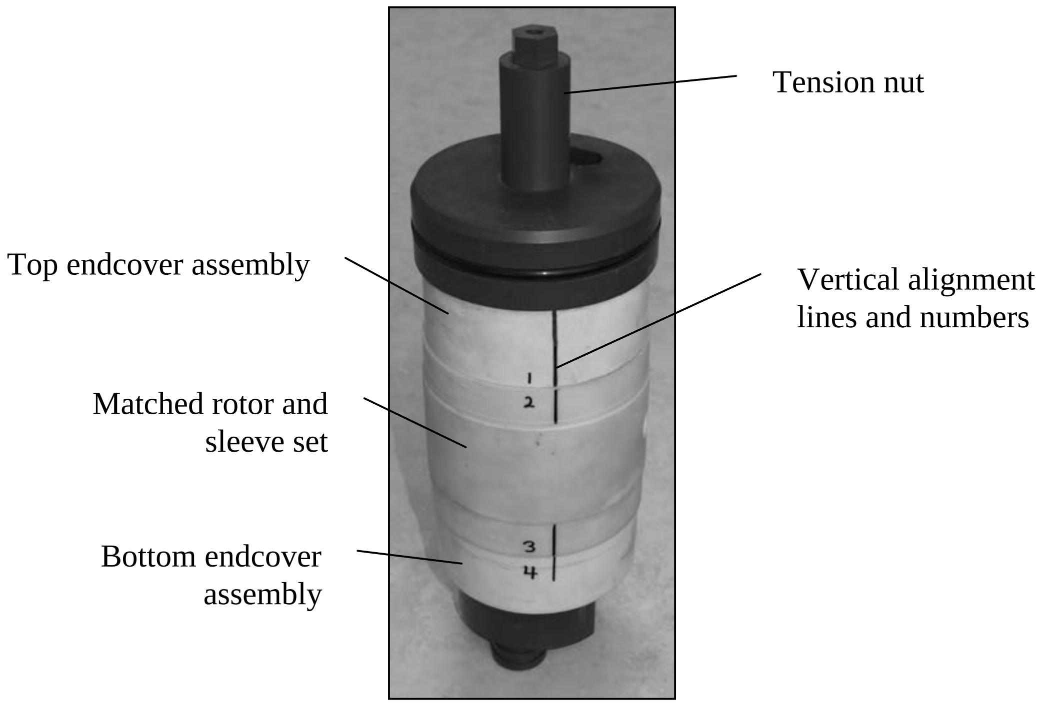


Figure 8-7 PX 15-60 Ceramic Cartridge

6. Remove the tension rod nut located at the top of the cartridge.

Note

This should be done in the vertical position to prevent damage to the ceramic assembly.

7. Carefully remove the top End Cover and inspect the ceramic face and PVC manifold for defects. Carefully remove mated rotor and sleeve set and check ceramic ducts and edges for defects.

CAUTION

Take care not to allow the rotor and sleeve to become separated. They can be slippery and be easily separated.

Each pair is a matched set and not interchangeable from one another or from each sets specific orientation. See the section on Mated Rotor Disassembly and Reassembly for more information.

8. Inspect all the ceramics and components for damage. Wash all of the components with clean soap and water. Stains may remain but are normal.

8.1.3 Cartridge Reassembly

This section describes the reassembly of the ceramic cartridge and it's components.

CAUTION

Do not attempt to reassemble any ceramic cartridge with damaged or chipped components.   Be sure all components are flushed with clean fresh water and that the rotor is free and clear and can be easily rotated inside its sleeve.

1. Reassemble cartridge by matching corresponding numbers previously marked 1-4 above.
2. Align vertical lines on Sleeve with corresponding vertical marks on the End Covers.
3. Center End Cover outer diameter with the sleeve outer diameter as close as possible.

Note

Some Pressure Exchangers use pins to keep the endcap and sleeves aligned and centered.

4. When the ceramic cartridge is centered and aligned tighten tension rod nut. (1/4 turn after snug)
5. Before sliding the cartridge back into the vessel use a wooden dowel rod to check to see that the rotor is free and clear and can be easily rotated inside the sleeve
6. When sliding the cartridge back into the vessel, carefully align the cartridge over the 2 low pressure adapter holes at the bottom of the

vessel. Use the alignment marks put in above during step 8.1.2, #1 to accomplish this alignment.

Caution

Be careful to properly align the cartridge with the low pressure adaptor ports over the low pressure adaptor holes. The 2 low pressure adaptor nipples at the bottom of the cartridge can be damaged if they are misaligned when slid into the vessel.

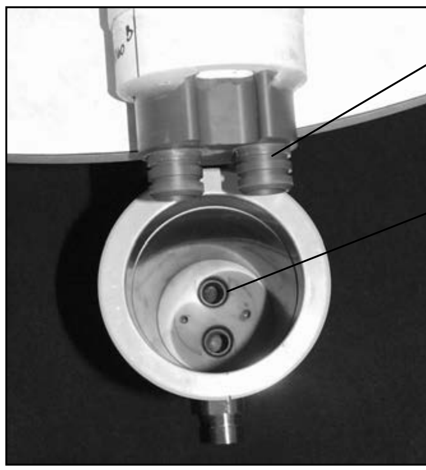


Figure 8-8 PX 15-60 Low Pressure Adaptor and Ports

7. Reassemble the vessel according to steps 3-1 in section 8.1.1.

8.1.4 Low Pressure Foundation and Adaptor Disassembly

This section describes the disassembly and reassembly of the low-pressure foundation and low-pressure adapter. See assembly drawings at back of manual for descriptions and exploded views of PX parts and assemblies.

1. Remove the 2ea, 3/8" x 16 UNC bolts at the bottom of the pressure vessel/low pressure foundation.
2. The foundation should now easily separate from the pressure vessel. It may be helpful to use a wedge between the vessel and the foundation as a pry.
3. The internal low-pressure adaptor is held in place by the same style of fiberglass-locking rings as the access cover. Remove fiberglass-locking rings by sliding them out of the vessel groove.

4. Once the locking rings have been removed the low-pressure adapter can be removed by tapping the vessel over a long piece of wood or PVC pipe.
5. Reassemble the low pressure foundation and low pressure adapter in reverse order of steps 1-4.

8.1.5 Mated Rotor and Sleeve Disassembly / Reassembly

This section describes how to separate the mated rotor and sleeve assembly. Care should be taken when handling all ceramics. Any damaged ceramics should be reported to ERI immediately.

Note

Care should be taken when handling all of the ceramic parts. There are extremely close tolerance fits and a clean work environment is essential.

1. Mark rotor and sleeve ends. They must be reassembled in their original orientation from end to end.
2. Set rotor and sleeve on a flat clean surface and slowly slide the sleeve off of the rotor.

CAUTION

It is easy for the rotor and sleeve to become misaligned and bind during this process. Do not force the separation process. If they become bound use hot water on the sleeve to loosen it away from the rotor. Contact ERI if the problem persists.

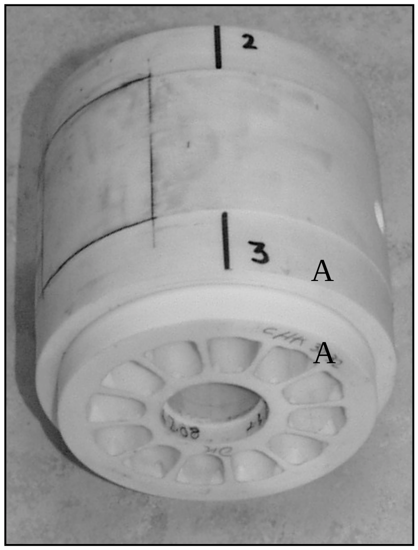


Figure 8-9 Rotor and Sleeve Assembly

3. Inspect and clean rotor and sleeve mating surfaces. Stains are normal as long as the finishes on the ceramic surfaces are glassy and smooth to the touch.
4. Set Rotor on a flat clean surface and slowly slide the sleeve onto the rotor. Be sure the marks you made in step 1 of this section are on the same sides.

CAUTION

This is a very tight fit and requires skill. **Do not force the sleeve on** by pressing or hitting it. The sleeve should slide on easily. If they become bound use hot water on the sleeve to loosen it away from the rotor. Contact ERI if the problem persists.

5. Check to ensure the rotor is free and clear and can be rotated easily inside its mated sleeve.

8.2 Disassembly and Repair of PX 90 and 120

The PX 90 and 120 house two rotors and have 5 separate connections. The model number of your unit should appear on the outside of the vessel. Looking at the assembly drawings at the back of the manual should also help to determine which PX unit you have.

8.2.1 Vessel Disassembly /Reassembly and Rotor Inspection

This section describes how to access the PX cartridge to inspect for abnormalities, remove foreign material, and or to aid in evaluating the type of problem you are encountering. See assembly drawings at back of manual for descriptions and exploded views of PX parts and assemblies.

1. Remove Low Pressure (LP) inlet fitting from both ends of the PX. Be careful not to damage the victaulic sealing surface of the fitting. It is recommended to use a strap wrench if possible. This fitting uses a straight thread O-ring seal that will be approximately hand tight.
2. Remove cap screws (12).

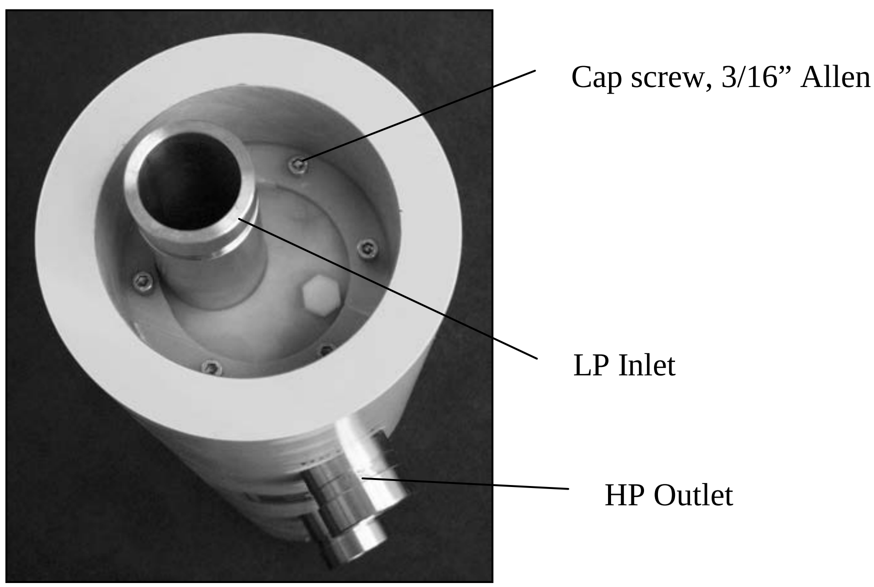


Figure 8-10 PX-120 Access Cover Assembly I

3. Remove fiberglass-locking rings (2 sets) by sliding them out of the vessel groove. After pressurizing the vessel the rings may be locked in place. If necessary, simply tap down on the fiberglass access cover to relieve the pressure on the rings and remove.

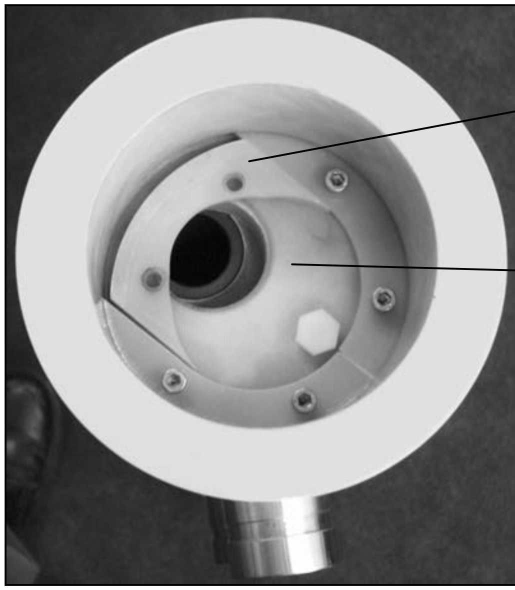


Figure 8-12 PX-120 Access Cover Assembly II

4. Reinstall the low pressure inlet fittings.
5. Remove both Access Covers by placing a coupling on the LP port fitting and using a pry-bar to pull off the access cover.

Note

Apply a liquid soap or any water-soluble lubricant to the ID of the vessel before attempting to remove the access cover.

Figure 8-13 Remove Access Cover Position I

Figure 8-14 Remove Access Cover Position II

6. After the Access Cover has been removed the PVC LP Nipple may or may not have come out with the Access Cover assembly. If not the nipple is held in by one O-ring and can be carefully pulled out by hand.

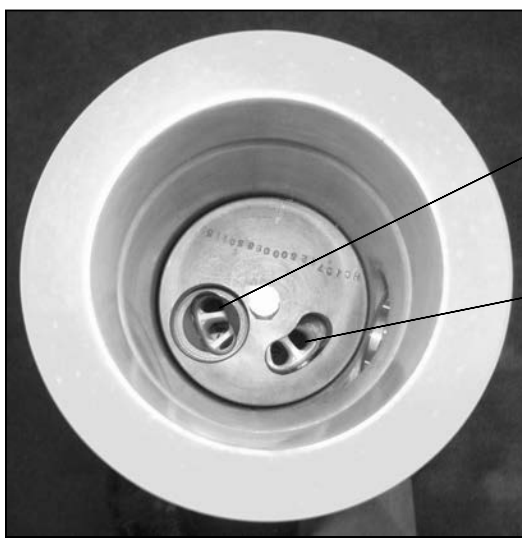


Figure 8-15 Internal Cartridge and Rotor

7. At this point you can easily access and see the rotor. Using a wooden dowel rod, spin each rotor and ensure that they rotate freely. Remove any foreign material that may be surrounding the cartridge. Thoroughly flush the unit with clean fresh water to free the rotors of any particulate matter that may have been lodged between the ceramic pieces.

Using a flash light and wooden dowel check the following:

F. Rotors are free and clear and can rotate easily.
G. Rotor duct walls have not been chipped and or broken.
H. Foreign debris and material has been removed from all components.
I. All o-rings are in good condition.
J. Check LP nipple for cracks or broken edges.
K. Check Access Cover for damage.

Note

If rotors do not rotate or there is visible damage to the duct walls or other ceramic components proceed to the cartridge disassembly procedure.

8. After all parts have been inspected and everything appears to be in good working condition the unit should be reassembled and tested in the system. To reassembly the vessel repeat steps 6 through 1 in reverse order.

Note

Use of sufficient lubrication on all o-rings and tight surfaces during the reassembly process is recommended. Liquid soap or any water-soluble lubricant is recommended.

8.2.2 Cartridge Disassembly

This section describes the complete tear down and repair of the PX Ceramic Cartridge. The cartridge should be disassembled only if problems persist or damaged ceramics have been observed. See assembly drawings at back of manual for descriptions and exploded views of PX parts and assemblies.

Note

Care should be taken when handling all of the ceramic parts. There are extremely close tolerance fits and a clean work environment is essential.

1. Mark the ceramic cartridge orientation inside the vessel and note that the small pressure equalization hole lines up with the LP outlet port.

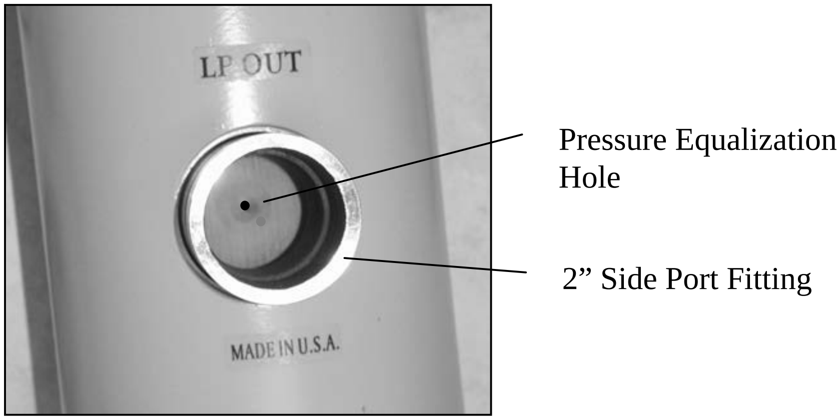


Figure 8-16 Pressure Equalization Hole and LP Outlet Port

2. Unscrew the 2 each, 2” side port fittings. They use a straight thread O-ring seal so a strap wrench should be sufficient.

CAUTION

This should be done with the PX in the horizontal position. The 2” side port fittings hold the PX cartridge in place. The cartridge will fall out of the vessel and may be damaged if vertical. Also protect the Victaulic seal area.

3. Slide the PX cartridge out of the vessel.
4. Mark ceramics for easy reassembly. Mark ceramics 1-8 to ensure the ceramics are later reassembled in the same position.

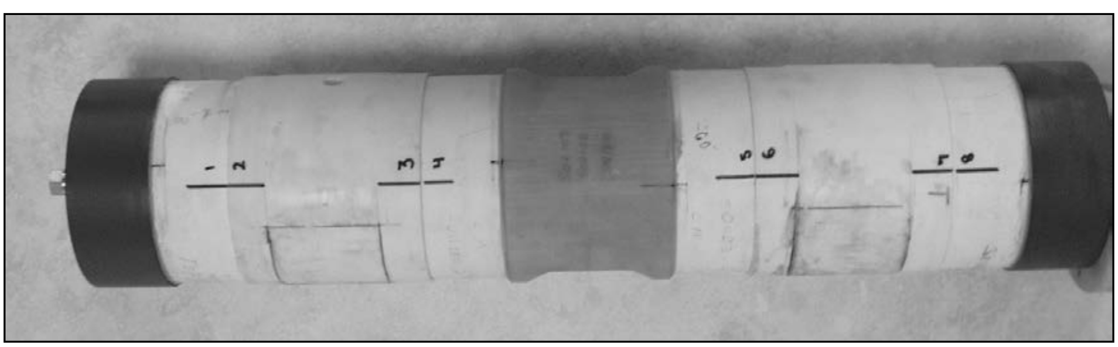


Figure 8-17 Horizontal Ceramic Cartridge Marked 1-8

5. Remove fiberglass glue band with a blade or flat head screwdriver. It should peel off. It is not important to save or reapply the bands. They are used to maintain alignment during shipping only.

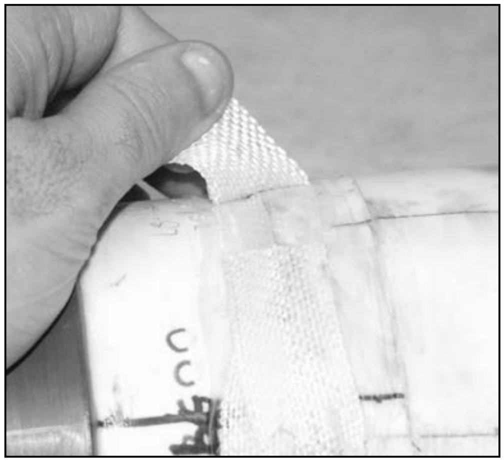


Figure 8-18 Remove Fiber Glass Tape

Note

Some pressure exchangers use pins to keep the endcap and sleeves aligned during shipping and reassembly.

6. Remove the tension rod nuts located at either end of the cartridge.

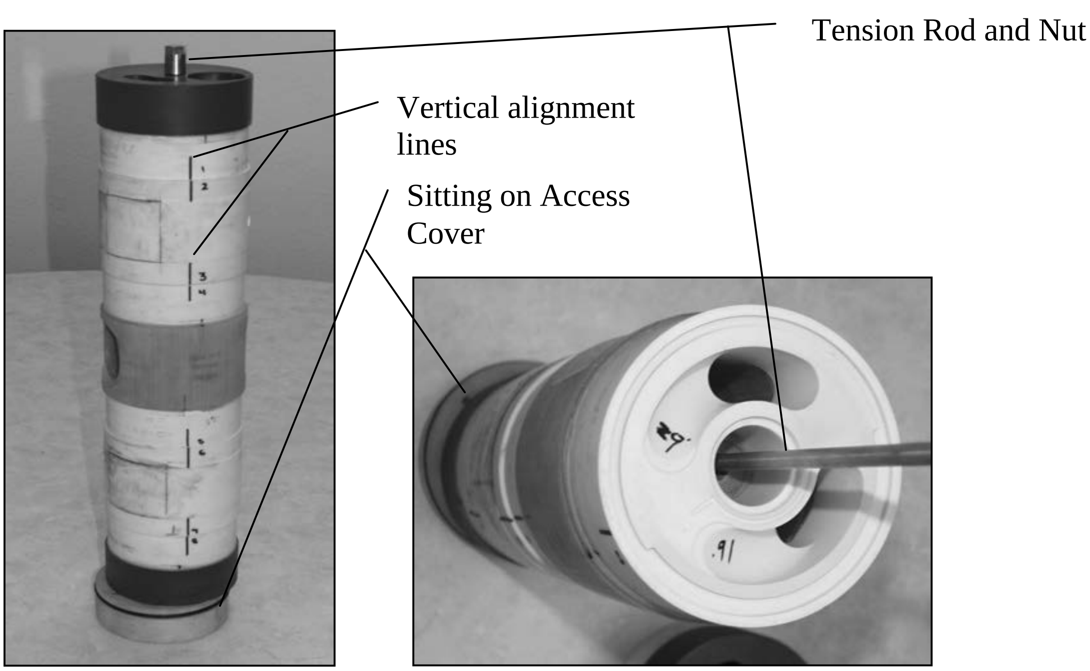


Figure 8-19 Vertical Assembly

Figure 8-20 Ceramics Assembly Looking Down

Note

This should be done in the vertical position to prevent damage to the ceramic assembly. It is helpful to use an access cover as a base to help stabilize the cartridge.

7. Carefully remove the top End Cover and inspect the ceramic face and PVC manifold for defects. Carefully remove mated rotor and sleeve set and check ceramic ducts and edges for defects.

CAUTION

Take care not to allow the rotor and sleeve to become separated. They can be slippery and be easily separated. Each pair is a matched set and not interchangeable from one another or from each sets specific orientation. See section 9.4 for more information.

8. Inspect all the ceramics and components for damage. Wash all of the components with clean soap and water. Stains may remain but are normal.

8.2.3 Cartridge Reassembly

This section describes the reassemble of the ceramic cartridge and it's components.

CAUTION

Do not attempt to reassemble any ceramic cartridge with damaged or chipped components. Be sure all components are flushed with clean fresh water and that the rotor is free and clear and can be easily rotated inside its sleeve.

6. Reassemble cartridge by matching corresponding numbers previously marked 1-8 above.
7. Align vertical lines on Sleeve with corresponding vertical marks on the End Covers.
8. Center End Cover outer diameter with the sleeve outer diameter as close as possible.

Note

Some Pressure Exchangers use pins to keep the endcap and sleeves aligned and centered.

9. When the ceramic cartridge is centered and aligned tighten tension rod nut seals. (Half a turn after snug)
10. Before sliding the cartridge back into the vessel use a wooden dowel rod to check to see that the rotors are free and clear and can be easily rotated inside the sleeve
11. Lay the vessel horizontally and insert the cartridge into the vessel. Aligning the LP vent hole with the LP outlet hole on the vessel.
12. Reinstall 2" port fittings and reassemble the vessel according to steps 6-1 in section 9.1.

8.2.4 Mated Rotor and Sleeve Disassembly / Reassembly

This section describes how to separate the mated rotor and sleeve assembly. Care should be taken when handling all ceramics. Any damaged ceramics should be reported to ERI immediately.

Note

Care should be taken when handling all of the ceramic parts. There are extremely close tolerance fits and a clean work environment is essential.

1. Mark rotor and sleeve ends. They must be reassembled in their original orientation from end to end.
2. Set rotor and sleeve on a flat clean surface and slowly slide the sleeve off of the rotor.

CAUTION

It is easy for the rotor and sleeve to become misaligned and bind during this process. Do not force the separation process. If they become bound use hot water on the sleeve to loosen it away from the rotor. Contact ERI if the problem persists.

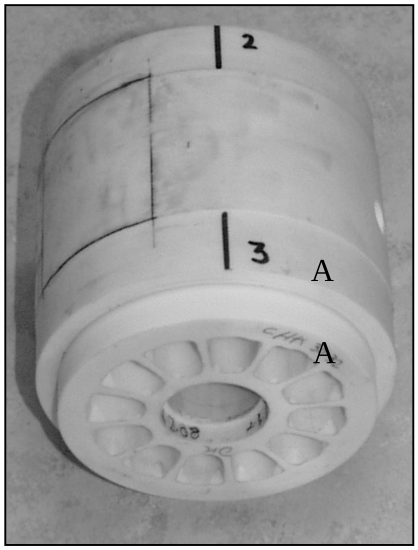


Figure 8-21 Rotor and Sleeve Assembly

3. Inspect and clean rotor and sleeve mating surfaces. Stains are normal as long as the finishes on the ceramic surfaces are glassy and smooth to the touch.
4. Set Rotor on a flat clean surface and slowly slide the sleeve onto the rotor. Be sure the marks you made in step 1 of this section are on the same sides.

CAUTION

This is a very tight fit and requires skill. **Do not force the sleeve on** by pressing or hitting it. The sleeve should slide on easily. If they become bound use hot water on the sleeve to loosen it away from the rotor. Contact ERI if the problem persists.

5. Check to ensure the rotor is free and clear and can be rotated easily inside its mated sleeve.

9.0 TROUBLE SHOOTING

This section is designed to guide the operator in determining the probable cause of the most frequently encountered problems. This section can only be a guide to solving potential problems within the Pressure Exchanger system and cannot contemplate all possible malfunctions, nor can it contain all possible ways to determine the cause of a malfunction. The best troubleshooting tool is the knowledge of the plant gained through experience. 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. Checking for continuity and solid contact can prevent hours of wasted effort.

3. Always inspect and test equipment or apparatus for possible cause of malfunction before performing replacement.

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

Table 8-1. Troubleshooting

SYMPTOM	PROBABLE CAUSE	CORRECTIVE ACTION
A. Excessive noise levels.	1. Operating PX unit(s) beyond rated flow rates on its low-pressure and/or the high pressure sides.	Immediately reduce flow rate through adjustment of PX booster pump and LP control valve and balance the system.
	2. Insufficient back pressure at low pressure outlet.	Increase feed pressure at the low pressure inlet and throttle the flow accordingly.
B. Excessive high pressure in RO system.	1. Main high-pressure pump is operating at too high a flow rate.	Determine 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 RO system.	Increase PX booster pump flow rate and low pressure control valve flow rate and balance system.
	3. Low pressure seawater feed flow is less than high pressure reject water outlet flow creating mixing and high outlet salinity.	See section 6.2
	4. A jammed or stalled rotor short circuits high pressure reject water with high pressure feed water and no exchange occurs. (PX audible noise will be absent)	See symptom D.
C. High Salinity in high pressure seawater feed stream.	1. Unbalanced system	See section 6.2.
	2. A jammed or stalled rotor short circuits high pressure reject water with high pressure feed water and no exchange occurs. (PX audible noise will be absent)	See symptom D.

	3. Operating PX unit(s) below rated flow rate results in low RPM resulting in increased mixing.	Increase H.P. seawater flow through PX booster pump. (Lower system recovery)
	4. Malfunctioning and/or stalled PX booster pump.	Check PX booster pump's rotation, operation, flows, and pressures.
D. Stalled Rotor. **1. No audible rotation** **2. Seawater at LP outlet** **3. Reject water at HP outlet**	1. After prolonged shutdowns biological growth can cause the rotor to stick	See disassembly and repair section 8 and remove access cover and check rotation.
	2. Operating system above rated pressure and flow capacity or below rated flow capacity.	See table 4.1
	3. Foreign debris or particles lodged in device.	See disassembly and repair section 8.
	4. System is not properly flow balanced.	See Section 6.2.
E. Irregular audible rotation. (putt, putt, putt)	1. Chipped / broken rotor ducts.	See disassembly and repair section 9 or 10.
F. Cannot build system pressure and/or excessive leakage.	1. High pressure pump failure.	Check high pressure pump performance.
	2. Open valve or leak in high-pressure system.	1. Check valve orientations. 2. Check membrane product tube interconnections.
	3. Excessive leakage from high pressure to low pressure within PX.	1. See disassembly and repair section 9 or 10 and check of damaged components.
G. Low high pressure reject flow.	1. Excessive differential pressure losses through RO membranes.	Clean RO membranes.

	2. Malfunctioning and/or stalled PX booster pump.	Check PX booster pump's operation, flows, and pressures.
H. Abnormal pulsations or vibration.	1. Air in system.	Bleed and purge all air from the system before applying high pressure.
I. External leakage and/or drips	1. Damaged O-rings.	Check and replace defective and/or suspected O-rings.
	2. Scratches inside pressure vessel.	Sand vessel sealing surface clean and smooth.
	3. Damaged low-pressure nipple adaptor on low-pressure foundation (PX-60).	Remove foundation and check the 2 nipples for cracks or damage.

10.0 ERI FIELD COMMISSIONING

The Technical Services staff of ERI offers commissioning service for all new PX related products whether it is in a field installation or at a RO 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.

10.1 FIELD SERVICE

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

Energy Recovery, Inc.
1908 Doolittle Drive
San Leandro, CA 94577
USA
Tel: +1 510 483 7370
Fax: +1 510 483 7371
Email: sales@energy-recovery.com
Web: www.energy-recovery.com

<u>High Pressure Ultrasonic Flow Meter</u>

DEREX Instuments and Valves
PO Box 2983
San Rafael CA 94912
Tel: 415.454.3729 / Fax: 415.454.3756
Web www.derex.com

Dynasonics
2200 South Street
Racine, WI 53404 USA
TEL: 800.535.3569 Toll-Free In the USA
262.639.6770
FAX: 800.732.8354 Toll-Free In the USA
262.639.2267
Web: www.dynasonics.com
Transit Time Ultrasonic Flow Meter Series TFXD (Wall mount unit)
Transit Time Ultrasonic Flow Meter Series TFXP (Portable unit)

11.0 REVISION LOG

Revision Log

Revision	Description	Date	Approval
A	2000 updates including PX-90 and 120	1/14/00	JPM
B	General updates & revisions	1/17/01	IBC
C	Fresh water flush and preservations updates	2/8/01	JPM
D	Edit and revue	2/14/01	JDA
E	Misc.	2/20/01	IBC
F	General Updates and revisions	7/6/01	JPM
G	General Updates and revisions	9/6/01	JPM
H	General Updates and revisions (plus to minus)	9/18/01	MYW
I	HP flow meter updates	11/2/01	GGP
J	Added Disassembly and Repair Section	5/30/03	JPM

12.0 WARRANTY & LIABILITY

Basic Product Warranty – ERI warrants its PX Pressure for a period of **two years** from date of shipment. This warranty covers repair or replacement, free of charge in the event of failure or malfunction as a result of defects in materials, workmanship or design. Requirements for this guarantee include maintaining accurate plant operating logs, use of accurate installed flow meters, and non-use of inappropriate chemicals, as per ERI's recommendations,

Remedy

If any PX Pressure Exchanger covered under this warranty shall fail, ERI will, at its option, either promptly repair or replace the faulty unit without charge to the buyer. Replacements are exclusive of freight, installation costs, handling fees, duties, or any other taxes.

Reasonable care

ERI shall not be liable for damage or wear to the PX caused by unprotected storage, abnormal operating conditions, accident, abuse, misuse, alterations or repair, or if the PX units were not installed in accordance with the printed operating instructions or any subsequent written instructions given to client by ERI.

Maximum operating flow and pressure limitation

Maximum operating flow through the PX, either on the low-pressure side or the high-pressure side, must not exceed the rated capacity of the PX rotors. Flows in the high-pressure side must be determined by direct measurement using an ultrasonic high-pressure flow meter or similar instrument. Maximum operating pressure must not exceed 1,200 psi.

Client Responsibilities

Initial piping system flushing

After the PX units are installed, client must insure that all piping is cleaned and flushed with water in a way that all construction debris is removed from the system and has not lodged in the PX.

Seawater filtration

Seawater flowing to the PX units must be filtered in such a way that all particles larger than 5 microns are removed prior to the seawater entering the PX.

Isolation from membrane cleaning chemicals

PX units must be completely isolated from the reverse osmosis system whenever a chemical cleaning of the membranes is being performed. If isolation valves are not provided in the system design, the PX units must be removed during such cleanings.

Chemical Additives

Some chemical additives are known to be the cause of operational failure of Pressure Exchangers. These chemicals include, but are not limited to polyacrylates, occasionally used for scaling prevention. These chemicals can cause Pressure Exchanger failure by forming a sticky substance, which physically jams the PX mechanism. It is the Client's responsibility to avoid use of such chemicals or other similar materials. Pressure Exchanger malfunctions found to be caused by the presence of such precipitated materials are not covered by ERI's warranty.

PX flushing during extended shutdowns

In preparation for extended plant shutdowns, PX units must be flushed with permeate following ERI's recommendations.

Record keeping and data reporting

Client shall maintain operating records for each PX train in the reverse osmosis system. These records must show that the PX units are operated consistently within the maximum flow and pressure limitations set forth above. At least once every day client will fill an operating log containing all of the operating parameters required by ERI. This information shall be faxed to ERI weekly during the first month after startup.

Client will provide access to ERI to all PX and Reverse Osmosis plant operating records at any time during normal working hours. Denial of such access or failure of client to maintain complete records shall void this warranty.

Limitation on Warranties and Remedies

The foregoing warranty and remedies are sole and exclusive and in lieu of any rights and remedies otherwise available at law or in equity, and are void unless Client has complied with each and every Client Obligation as provided above. Implied warranties of merchantability and fitness for a particular purpose are excluded.

Consequential Damages

In no event shall ERI be responsible or held liable for any indirect, special, incidental or consequential type damages including, by way of example, loss of profit, loss of use or business interruption, or damage caused by installation or use of ERI's products, however caused. ERI's aggregate liability shall not exceed an amount equal to the purchase price.

Note

A complete and accurate operating log must be submitted with all warranty claims.

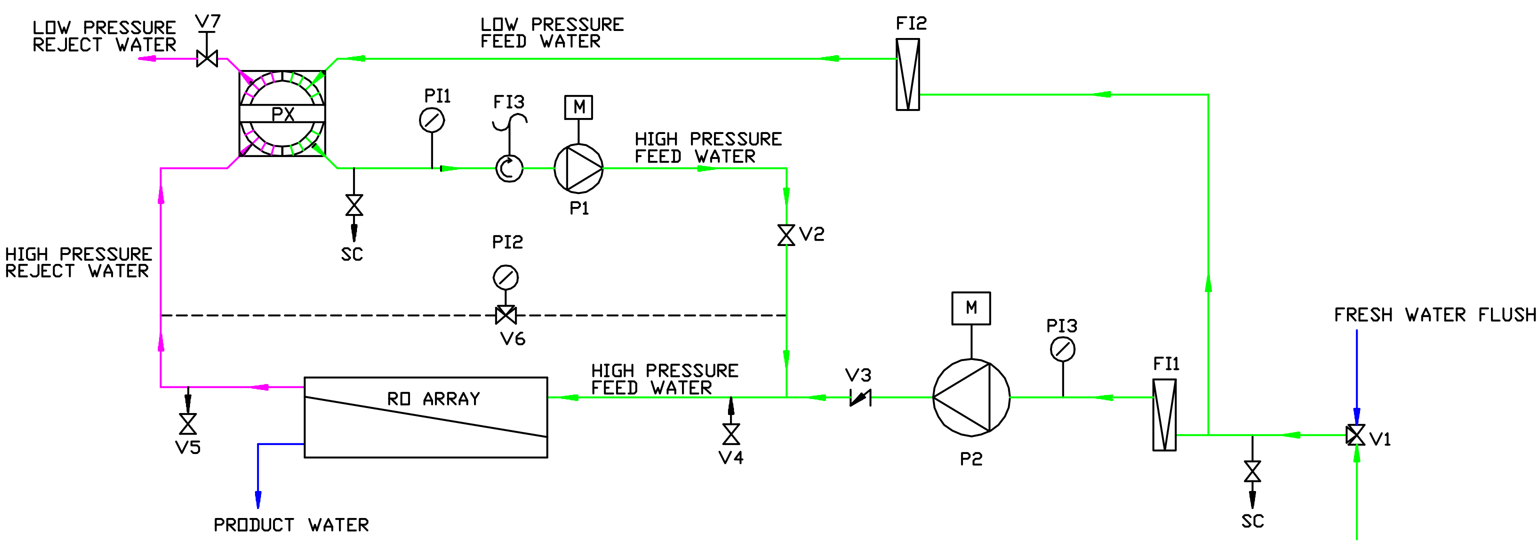
13.0 DRAWINGS AND DIAGRAMS

REV	DESCRIPTION	DATE	APPROVED
–	INITIAL RELEASE	11/17/00	
A	NOTE 2, REJECT – 1GPM/UNIT.	1/10/01	
B	CHANGED POSITION OF V8	6/11/01	
C	ADDED NOTE # 11.	7-6-01	
D	UPDATES AND NEW PX DIAGRAM.	10-24-01	

FI3	FLOW METER, PX HP OUTLET (SEE NOTE 8)	N/A	800-1175 PSI MAX
FI2	FLOW METER, PX LP INLET	N/A	100 PSI MAX
FI1	FLOW METER, MAIN HP PUMP (OPTIONAL)	N/A	100 PSI MAX
P2	MAIN HIGH PRESSURE PUMP	STAINLESS	800-1200 PSI
P1	PX BOOST PUMP	STAINLESS	800-1200 PSI (3)
PI3	MAIN HP PUMP / PX LP INLET PRESSURE	STAINLESS	100 PSI MAX
PI2	MEMBRANE DP & PX HP INLET PRESSURE	STAINLESS	800-1200 PSI
PI1	PX HP OUTLET / P1 INLET PRESSURE	STAINLESS	800-1200 PSI
SC	SAMPLE CONNECTION	VARIES	VARIES
V7	PX LP IN AND LP OUT FLOW CONTROL VALVE	PVC	100 PSI MAX
V6	MEMBRANE DP GAUGE VALVE	STAINLESS	800-1200 PSI
V5	FULL FLOW CLEANING LOOP VALVE	STAINLESS	800-1200 PSI (9)
V4	FULL FLOW CLEANING LOOP VALVE	STAINLESS	800-1200 PSI (9)
V3	HP CHECK VALVE	STAINLESS	800-1200 PSI
V2	CLEANING ISOLATON AND/OR CONTROL VALVE	STAINLESS	800-1200 PSI
V1	FRESH WATER FLUSH VALVE	PVC	100 PSI MAX
P&ID #	DESCRIPTOIN	TYPICAL MATERIAL	TYPICAL PRESSURE

NOTES:

1. MAIN HIGH PRESSURE (HP) PUMP FLOW = PRODUCT FLOW + (APPROX. 1 GPM X # OF PX UNITS)
2. PX BOOST PUMP FLOW = REJECT FLOW – (APPROX. 1 GPM X # OF PX UNITS)
3. PX BOOST PUMP DIFFERENTIAL PRESS (DP) = MEMBRANE DP + PX DP + LINE LOSSES
4. PRODUCT FLOW AND REJECT FLOW ARE INDEPENDENT. PRODUCT FLOW IS DICTATED BY MAIN HP PUMP CURVE (SEE NOTE 1). REJECT FLOW IS DICTATED BY THE PX BOOSTER PUMP CURVE (SEE NOTE 2).
5. FLOW RATE THROUGH PRESSURE EXCHANGERS SHOULD BE ADJUSTABLE USING VFD DRIVE ON PX BOOSTER PUMP OR V2 IF NO VFD IS USED.
6. MAIN SYSTEM PRESSURE AND PRODUCT FLOW RATE CAN BE MADE ADJUSTABLE BY APPLYING A VFD DRIVE TO MAIN HP PUMP.
7. FRESH WATER FLUSH IS REQUIRE TO KEEP PRESSURE EXCHANGER AND MEMBRANES FREE OF BIOLOGICAL GROWTH DURING SHUTDOWN. OPERATE UNIT NORMALLY DURING FRESH WATER FLUSH CYCLE. SEE START / STOP PROCEDURES IN SECTION 6.1.
8. HIGH PRESSURE FLOW METER (FI3) SHOULD BE APPLIED AT PX BOOSTER PUMP FOR EASY OPERATION AND BALANCING OF PX FLOWS.
9. CLEANING VALVES WILL BE OPEN DURING CLEANING AND SUBJECT TO LOW PRESSURE. DURING NORMAL OPERATION, VALVES WILL BE CLOSED AND SUBJECT TO HIGH PRESSURE.
10. HIGH PRESSURE SWITCH AND RELIEF VALVE SHOULD BE INSTALLED IN HIGH PRESSURE PORTION OF RO LOOP AS REQUIRED BY THE APPLICABLE SAFETY STANDARDS.
11. AN OPTIONAL HIGH PRESSURE BY-PASS VALVE MAY BE APPLIED AT THE OUTLET OF THE RO MEMBRANES FOR MANUAL AND/OR AUTOMATIC CONTROL OF THE PRESSURIZATION AND AND DEPRESSURIZATION RATE OF THE RO MEMBRANES.



1	SH	REVISION STATUS
-	REV	OF SHEETS

FOR CUSTOMER RELEASE

?
NEXT HIGHER ASSEMBLY
APPLICATION

DRAWN JOHN M. DATE 11/17/00
CHECKED DATE
APPROVED DATE
ISSUE DATE
CONTRACT NO.

ENERGY RECOVERY, INC.
1908 Doolittle Drive, San Leandro, CA 94577

PX INSTALLATION
P&ID DIAGRAM
TYPICAL CONFIGURATION

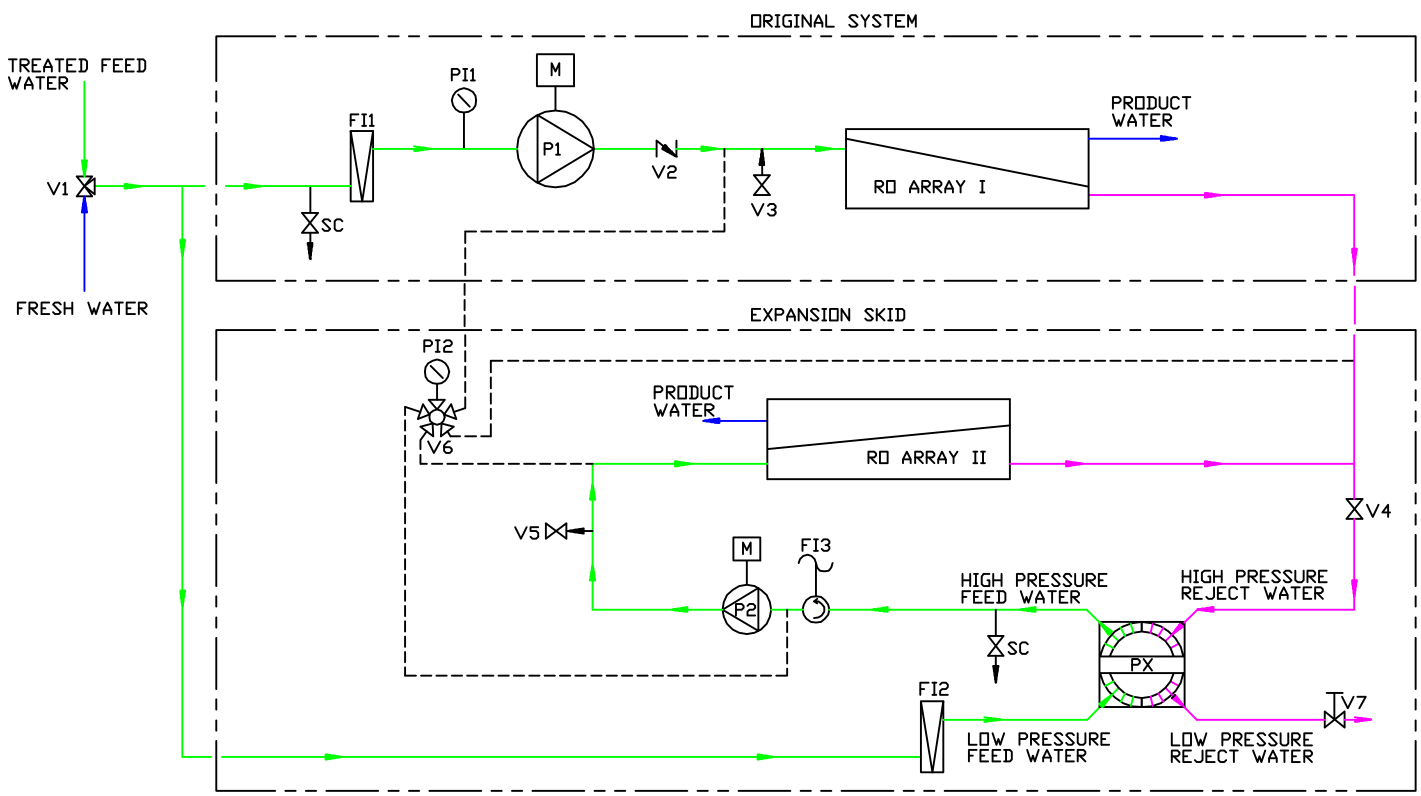
SIZE E | CAGE NO N/A | DWG NO JPM-111700-1 | REV D
SCALE N/A | SHEET 1

FI3	FLOW METER, PX HP OUTLET (SEE NOTE 8)	N/A	800-1200 PSI MAX
FI2	FLOW METER, PX LP INLET	N/A	100 PSI MAX
FI1	FLOW METER, MAIN HP PUMP (OPTIONAL)	N/A	100 PSI MAX
P2	PX BOOST PUMP	STAINLESS	800-1200 PSI (3)
P1	MAIN HIGH PRESSURE PUMP	STAINLESS	800-1200 PSI
PI2	HIGH PRESSURE SELECTOR GAUGE	STAINLESS	800-1200 PSI
PI1	MAIN HP PUMP / PX LP INLET PRESSURE	STAINLESS	100 PSI MAX
V7	LP IN AND LP OUT FLOW CONTROL VALVE	PVC	100 PSI MAX
V6	HIGH PRESSURE SELECTOR VALVE	STAINLESS	800-1200 PSI
V5	FULL FLOW CLEANING LOOP VALVE (SEE NOTE ?)	STAINLESS	800-1200 PSI (9)
V4	CLEANING ISOLATON AND/OR CONTROL VALVE	STAINLESS	800-1200 PSI
V3	FULL FLOW CLEANING LOOP VALVE	STAINLESS	800-1200 PSI (9)
V2	HP CHECK VALVE	STAINLESS	800-1200 PSI
V1	FRESH WATER FLUSH VALVE	PVC	100 PSI MAX
P&ID #	DESCRIPTOIN	TYPICAL MATERIAL	TYPICAL PRESSURE

REVISIONS			
REV	DESCRIPTION	DATE	APPROVED
-	INITIAL RELEASE	10/23/01	

NOTES:

1. MAIN HIGH PRESSURE (HP) PUMP FLOW = PRODUCT FLOW + (APPROX. 1 GPM X # OF PX UNITS)
2. PX BOOST PUMP FLOW = REJECT FLOW - (APPROX. 1 GPM X # OF PX UNITS)
3. PX BOOST PUMP DIFFERENTIAL PRESS (DP) = MEMBRANE DP + PX DP + LINE LOSSES
4. PRODUCT FLOW AND REJECT FLOW ARE INDEPENDENT. PRODUCT FLOW IS DICTATED BY MAIN HP PUMP CURVE (SEE NOTE 1). REJECT FLOW IS DICTATED BY THE PX BOOSTER PUMP CURVE (SEE NOTE 2).
5. FLOW RATE THROUGH PRESSURE EXCHANGERS SHOULD BE ADJUSTABLE USING VFD DRIVE ON PX BOOSTER PUMP OR V4 IF NO VFD IS USED.
6. MAIN SYSTEM PRESSURE AND PRODUCT FLOW RATE CAN BE MADE ADJUSTABLE BY APPLYING A VFD DRIVE TO MAIN HP PUMP.
7. FRESH WATER FLUSH IS REQUIRE TO KEEP PRESSURE EXCHANGER AND MEMBRANES FREE OF BIOLOGICAL GROWTH DURING SHUTDOWN. OPERATE UNIT NORMALLY DURING FRESH WATER FLUSH CYCLE. SEE START AND STOP PROCEDURES IN SECTION 6.1.
8. HIGH PRESSURE FLOW METER (FI3) SHOULD BE APPLIED AT THE PX BOOSTER PUMP FOR EASY OPERATION AND BALANCING OF PX FLOWS.
9. CLEANING VALVES WILL BE OPEN DURING CLEANING AND SUBJECT TO LOW PRESSURE. DURING NORMAL OPERATION, VALVES WILL BE CLOSED AND SUBJECT TO HIGH PRESSURE.
10. HIGH PRESSURE SWITCH AND RELIEF VALVE SHOULD BE INSTALLED IN HIGH PRESSURE PORTION OF RO LOOP AS REQUIRED BY THE APPLICABLE SAFETY STANDARDS.
11. AN OPTIONAL HIGH PRESSURE BY-PASS VALVE MAY BE APPLIED AT THE OUTLET OF THE RO MEMBRANES FOR MANUAL AND/OR AUTOMATIC CONTROL OF THE PRESSURIZATION AND AND DEPRESSURIZATION RATE OF THE RO MEMBRANES.



PRELIMINARY

FOR CUSTOMER RELEASE

?	
NEXT HIGHER ASSEMBLY	
APPLICATION	
DRAWN	JOHN M.
CHECKED	
APPROVED	
ISSUE DATE	
CONTRACT NO.	

ENERGY RECOVERY, INC.

1908 Doolittle Drive, San Leandro, CA 94577

PX INSTALLATION P&ID DIAGRAM MAXIMUM EXPANSION

SIZE	CAGE NO	DWG NO	REV
E	N/A	JPM-102301-1	-

SCALE N/A SHEET 1

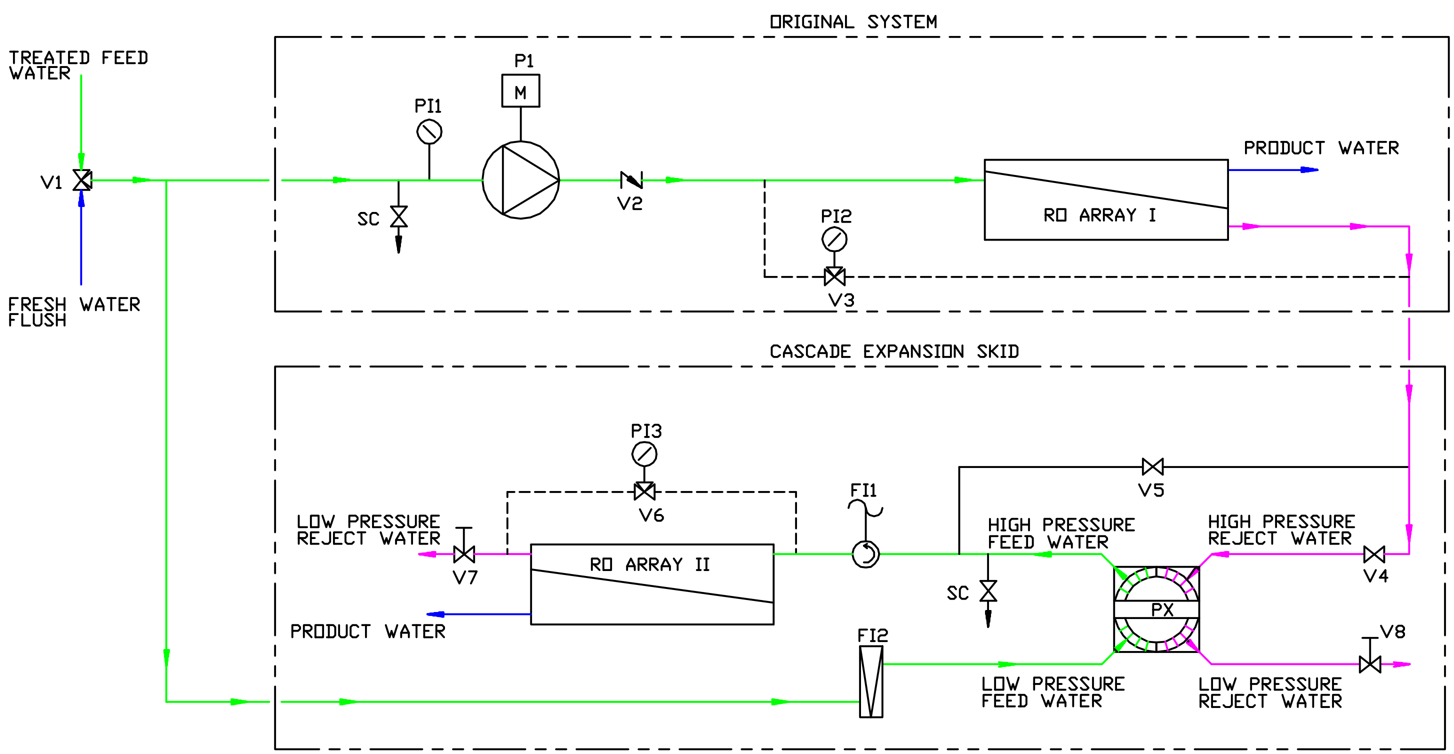
1	SH	REVISION STATUS OF SHEETS
-	REV	

REV	DESCRIPTION	DATE	APPROVED
-	INITIAL RELEASE	10/22/01	

P&ID #	DESCRIPTOIN	TYPICAL MATERIAL	TYPICAL PRESSURE
FI2	FLOW METER, PX LOW PRESSURE INLET	N/A	100 PSI MAX
FI1	FLOW METER, PX HIGH PRESSURE OUTLET	N/A	800-1200 PSI
P1	MAIN HIGH PRESSURE PUMP	STAINLESS	800-1200 PSI
PI3	HIGH PRESSURE SELECTOR GAUGE	STAINLESS	800-1200 PSI
PI2	HIGH PRESSURE SELECTOR GAUGE	STAINLESS	800-1200 PSI
PI1	HP PUMP P1 INLET / PX LP INLET PRESSURE	STAINLESS	100 PSI MAX
SC	SAMPLE CONNECTION	VARIES	VARIES
V8	PX LP IN AND LP OUT FLOW CONTROL VALVE	PVC	100 PSI MAX
V7	HP CONCENTRATE VALVE (SEE NOTE 5)	STAINLESS	800-1200 PSI
V6	HIGH PRESSURE GAUGE SELECTOR VALVE	STAINLESS	800-1200 PSI
V5	CLEANING BYPASS VALVE	STAINLESS	800-1200 PSI
V4	CLEANING ISOLATION VALVE	STAINLESS	800-1200 PSI
V3	HIGH PRESSURE GAUGE SELECTOR VALVE	STAINLESS	800-1200 PSI
V2	HP CHECK VALVE	STAINLESS	800-1200 PSI
V1	FRESH WATER FLUSH VALVE	PVC	100 PSI MAX

NOTES:

1. THOROUGHLY READ PX O&M MANUAL BEFORE ATTEMPTING TO DESIGN OR OPERATE A SYSTEM BUILT AROUND PRESSURE EXCHANGER TECHNOLOGY.
2. BALANCED PX FLOW ------> FI1 = FI2
3. LOW PRESSURE INLET/OUTLET PX FLOW IS CONTROLLED BY V8.
4. AN ENERGY RECOVERY TURBINE (ERT) MAY BE USED IN PLACE OF V7 TO IMPROVE THE OVERALL SYSTEM EFFICIENCY.
5. MAIN SYSTEM HIGH PRESSURE IS CONTROLLED USING V7 AND OR AN ERT.
6. FRESH WATER FLUSH IS REQUIRE TO KEEP PRESSURE EXCHANGER AND MEMBRANES FREE OF BIOLOGICAL GROWTH DURING SHUTDOWN. FLUSH UNDER LOW PRESSURE.
7. CLEANING BYPASS VALVE V5 WILL BE OPEN DURING CLEANING. V4 AND V8 SHOULD BE CLOSED. CLEANING SOLUTION SHOULD NOT BE ALLOWED TO PASS THROUGH PX.
8. HIGH PRESSURE SWITCH AND RELIEF VALVE SHOULD BE INSTALLED IN HIGH PRESSURE PORTION OF RO LOOP AS REQUIRED BY THE APPLICABLE SAFETY STANDARDS.
9. HIGH PRESSURE FLOW METER FI1 COULD BE REPLACE BY ADDING LOW PRESSURE FLOW METERS TO ARRAY II'S REJECT AND PRODUCT FLOWS.



PRELIMINARY

1	SH	REVISION STATUS
-	REV	OF SHEETS

FOR CUSTOMER RELEASE

ENERGY RECOVERY, INC.

PX INSTALLATION
P&ID DIAGRAM
CASCADE CONFIGURATION

DRAWN JOHN M. DATE
CHECKED DATE
APPROVED DATE
ISSUE DATE
CONTRACT NO.

?
NEXT HIGHER ASSEMBLY
APPLICATION

SIZE E | CAGE NO N/A | DWG NO JPM-102201-1 | REV -
SCALE N/A | SHEET 1

00405-015 BILL OF MATERIAL

ITEM NO.	QTY.	PART NO.	DESCRIPTION	MATERIAL
1	1	00430-01	VESSEL, PRESSURE, E.R. TYPE, SINGLE 4"	FIBERGLASS
2	1	00429-015	ASSY, INTERNALS, PX-15	CERAMIC/PVC
3	1	LPA2	ADAPTER, LOW PRESSURE	FIBERGLASS
4	2	00467	NIPPLE, FOUNDATION	PVC
5	2	00459	RING, LOCK	FIBERGLASS
6	1	AC1	COVER, ACCESS, INLET, HP	FIBERGLASS
7	1	BHP1	INLET, HP, 1" VIC	254SMO/AL-6XN
8	1	00455	RING, THRUST, SINGLE ROTOR, 4"	PVC
9	6	20-0001	SHCS, 1/4-20 X 3/4" LG	316 SS
10	3	2-347	O-RING, -347	BUNA-N
11	12	2-121	O-RING, -121	BUNA-N
12	2	20-0028	WASHER, FLAT, 3/8"	316 SS
13	2	20-0036	HHB, 3/8-16 X 6 1/2" LG	316 SS
14	1	RR2	RETAINER, O-RING	SEE PART DWG
15	1	FHP2	PORT, 1 1/2" NPS - 1" VICTUALIC	254 SMO
16	1	2-217	O-RING, -217	BUNA-N
17	1	00445	ASSY, FOUNDATION, LOW PRESSURE	PVC

00405-025 BILL OF MATERIAL

ITEM NO.	QTY.	PART NO.	DESCRIPTION	MATERIAL
1	1	00430-01	VESSEL, PRESSURE, E.R. TYPE, SINGLE 4"	FIBERGLASS
2	1	00429-025	ASSY, INTERNALS, PX-25	CERAMIC/PVC
3	1	LPA2	ADAPTER, LOW PRESSURE	FIBERGLASS
4	2	00467	NIPPLE, FOUNDATION	PVC
5	2	00459	RING, LOCK	FIBERGLASS
6	1	AC1	COVER, ACCESS, INLET, HP	FIBERGLASS
7	1	BHP1	INLET, HP, 1" VIC	254SMO/AL-6XN
8	1	00455	RING, THRUST, SINGLE ROTOR, 4"	PVC
9	6	20-0001	SHCS, 1/4-20 X 3/4" LG	316 SS
10	3	2-347	O-RING, -347	BUNA-N
11	12	2-121	O-RING, -121	BUNA-N
12	2	20-0028	WASHER, FLAT, 3/8"	316 SS
13	2	20-0036	HHB, 3/8-16 X 6 1/2" LG	316 SS
14	1	RR2	RETAINER, O-RING	SEE PART DWG
15	1	FHP2	PORT, 1 1/2" NPS - 1" VICTUALIC	254 SMO
16	1	2-217	O-RING, -217	BUNA-N
17	1	00445	ASSY, FOUNDATION, LOW PRESSURE	PVC

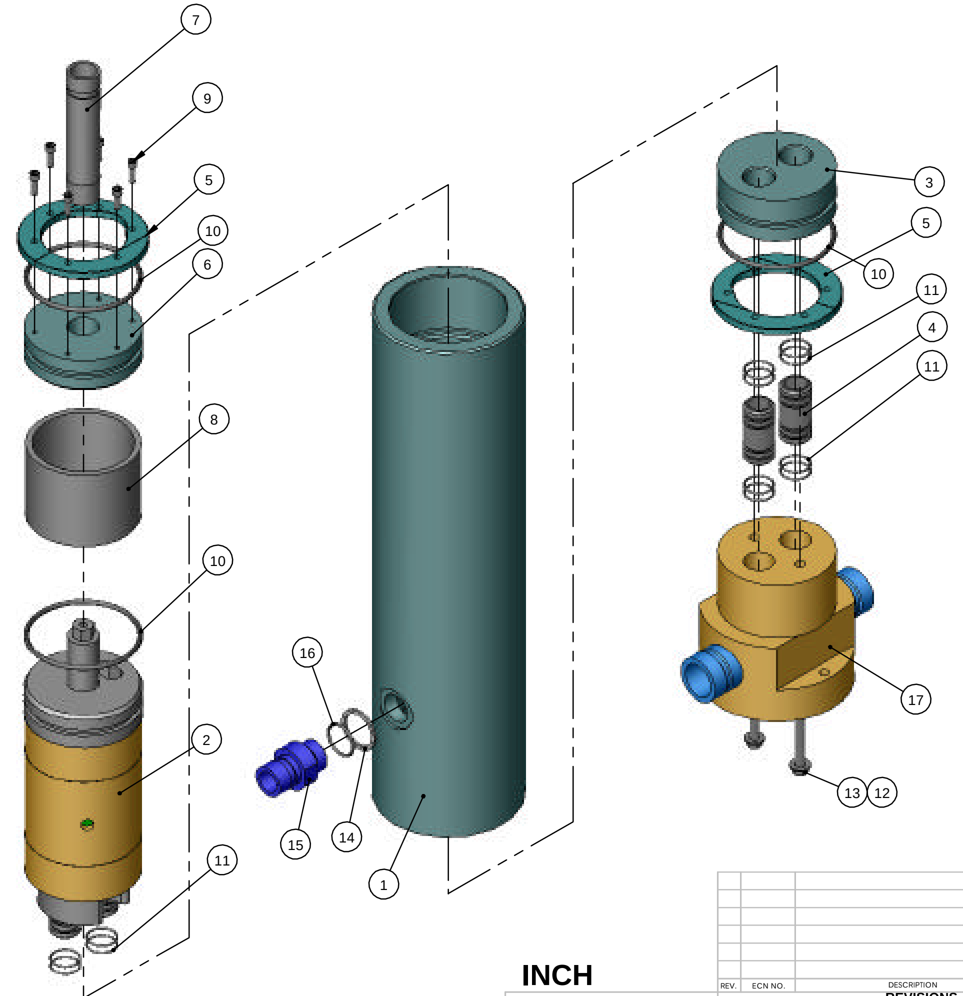
00405-040 BILL OF MATERIAL

ITEM NO.	QTY.	PART NO.	DESCRIPTION	MATERIAL
1	1	00430-01	VESSEL, PRESSURE, E.R. TYPE, SINGLE 4"	FIBERGLASS
2	1	00429-040	ASSY, INTERNALS, PX-40	CERAMIC/PVC
3	1	LPA2	ADAPTER, LOW PRESSURE	FIBERGLASS
4	2	00467	NIPPLE, FOUNDATION	PVC
5	2	00459	RING, LOCK	FIBERGLASS
6	1	AC1	COVER, ACCESS, INLET, HP	FIBERGLASS
7	1	BHP1	INLET, HP, 1" VIC	254SMO/AL-6XN
8	1	00455	RING, THRUST, SINGLE ROTOR, 4"	PVC
9	6	20-0001	SHCS, 1/4-20 X 3/4" LG	316 SS
10	3	2-347	O-RING, -347	BUNA-N
11	12	2-121	O-RING, -121	BUNA-N
12	2	20-0028	WASHER, FLAT, 3/8"	316 SS
13	2	20-0036	HHB, 3/8-16 X 6 1/2" LG	316 SS
14	1	RR2	RETAINER, O-RING	SEE PART DWG
15	1	FHP2	PORT, 1 1/2" NPS - 1" VICTUALIC	254 SMO
16	1	2-217	O-RING, -217	BUNA-N
17	1	00445	ASSY, FOUNDATION, LOW PRESSURE	PVC

00405-060 BILL OF MATERIAL

ITEM NO.	QTY.	PART NO.	DESCRIPTION	MATERIAL
1	1	00430-01	VESSEL, PRESSURE, E.R. TYPE, SINGLE 4"	FIBERGLASS
2	1	00429-060	ASSY, INTERNALS, PX-60	CERAMIC/PVC
3	1	LPA2	ADAPTER, LOW PRESSURE	FIBERGLASS
4	2	00467	NIPPLE, FOUNDATION	PVC
5	2	00459	RING, LOCK	FIBERGLASS
6	1	AC1	COVER, ACCESS, INLET, HP	FIBERGLASS
7	1	BHP1	INLET, HP, 1" VIC	254SMO/AL-6XN
8	1	00455	RING, THRUST, SINGLE ROTOR, 4"	PVC
9	6	20-0001	SHCS, 1/4-20 X 3/4" LG	316 SS
10	3	2-347	O-RING, -347	BUNA-N
11	12	2-121	O-RING, -121	BUNA-N
12	2	20-0028	WASHER, FLAT, 3/8"	316 SS
13	2	20-0036	HHB, 3/8-16 X 6 1/2" LG	316 SS
14	1	RR2	RETAINER, O-RING	SEE PART DWG
15	1	FHP2	PORT, 1 1/2" NPS - 1" VICTUALIC	254 SMO
16	1	2-217	O-RING, -217	BUNA-N
17	1	00445	ASSY, FOUNDATION, LOW PRESSURE	PVC

NOTES:
1. SEE ASSEMBLY PROCEDURE FOR INSTRUCTIONS.



TYPICAL ASSEMBLY

REV.	ECN NO.	DESCRIPTION	BY	DATE

REVISIONS

INCH

UNLESS OTHERWISE SPECIFIED:
TOLERANCES:
FRACTIONAL: ± 1/32"
ANGULAR: MACH ±.5°
BEND ±1°
TWO PLACE DECIMAL: ±.01"
THREE PLACE DECIMAL: ±.005"
FOUR PLACE DECIMAL: ±.0002"
SURFACE FINISH:
ON PART 125 RMS
ON O-RING SURFACES 32 RMS
DIMENSIONING AND TOLERANCING PER ANSI Y14.5M (LATEST)
FINISH:
MATERIAL:
SHOWN

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PRODUCT
DRAWING STATUS

DRAWN	RAC	02/05/2003
CHECKED	TLS	03/18/2003
ENG APPR.	RLS	03/18/2003

THIRD ANGLE PROJECTION

ENERGY RECOVERY INC.
1908 Doolittle Drive, San Leandro, CA 94577
Ph. (510)483-7370 / Fax: (510)483-7371
www.energy-recovery.com

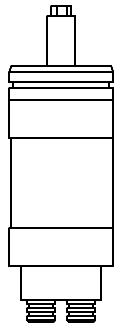
TITLE: ASSY, SINGLE ROTOR PINNED

SIZE: C | DWG. NO.: 00405 | REV: A

SCALE: 1:3 | WEIGHT: | SHEET 1 OF 3

NOTES:
1. SEE ASSEMBLY PROCEDURES FOR INSTRUCTIONS.

ITEM NO.	QTY.	PART NO.	DESCRIPTION	MATERIAL
1	1	00400	MATCHED SET, 4.0", ROTOR AND SLEEVE	CERAMIC
2	1	00495-060	ASSY, ENDCOVER, BTM, PX-60	PVC/CERAMIC
3	1	00485-060	ASSY, ENDCOVER, TOP, PX-60	PVC/CERAMIC
4	1	00474	ROD, TENSION, SINGLE ROTOR	MONEL
5	1	RODNUT1	NUT, TENSION	PVC
6	1	2-212	O-RING, -212	BUNA-N
7	6	40-0000	DOWEL, 3/32" DIA X 1/4" LG	ACETAL

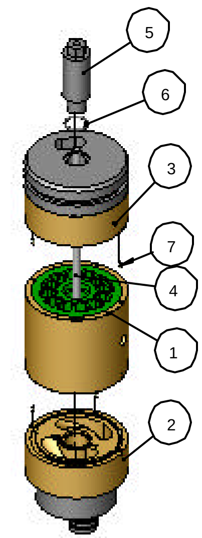


TYPICAL CONFIGURATION AFTER ASSEMBLY

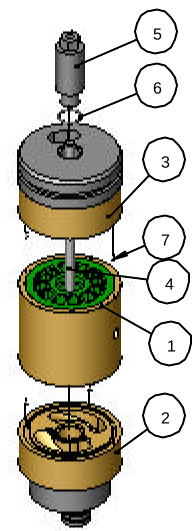
ITEM NO.	QTY.	PART NO.	DESCRIPTION	MATERIAL
1	1	00400	MATCHED SET, 4.0", ROTOR AND SLEEVE	CERAMIC
2	1	00495-040	ASSY, ENDCOVER, BTM, PX-40	PVC/CERAMIC
3	1	00485-040	ASSY, ENDCOVER, TOP, PX-40	PVC/CERAMIC
4	1	00474	ROD, TENSION, SINGLE ROTOR	MONEL
5	1	RODNUT1	NUT, TENSION	PVC
6	1	2-212	O-RING, -212	BUNA-N
7	6	40-0000	DOWEL, 3/32" DIA X 1/4" LG	ACETAL

ITEM NO.	QTY.	PART NO.	DESCRIPTION	MATERIAL
1	1	00400	MATCHED SET, 4.0", ROTOR AND SLEEVE	CERAMIC
2	1	00495-025	ASSY, ENDCOVER, BTM, PX-25	PVC/CERAMIC
3	1	00485-025	ASSY, ENDCOVER, TOP, PX-25	PVC/CERAMIC
4	1	00474	ROD, TENSION, SINGLE ROTOR	MONEL
5	1	RODNUT1	NUT, TENSION	PVC
6	1	2-212	O-RING, -212	BUNA-N
7	6	40-0000	DOWEL, 3/32" DIA X 1/4" LG	ACETAL

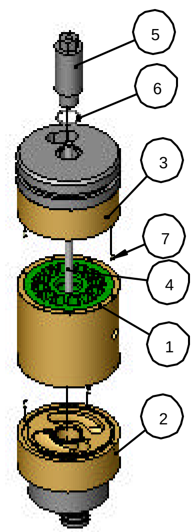
ITEM NO.	QTY.	PART NO.	DESCRIPTION	MATERIAL
1	1	00400	MATCHED SET, 4.0", ROTOR AND SLEEVE	CERAMIC
2	1	00495-015	ASSY, ENDCOVER, BTM, PX-15	PVC/CERAMIC
3	1	00485-015	ASSY, ENDCOVER, TOP, PX-15	PVC/CERAMIC
4	1	00474	ROD, TENSION, SINGLE ROTOR	MONEL
5	1	RODNUT1	NUT, TENSION	PVC
6	1	2-212	O-RING, -212	BUNA-N
7	6	40-0000	DOWEL, 3/32" DIA X 1/4" LG	ACETAL



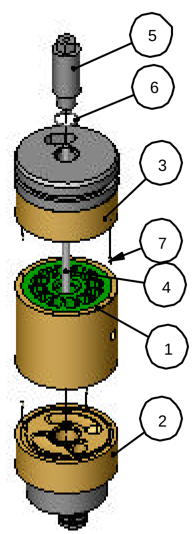
00429-060



00429-040



00429-025



00429-015

REV. | ECN NO. | DESCRIPTION | BY | DATE

REVISIONS

INCH

UNLESS OTHERWISE SPECIFIED:
TOLERANCES:
FRACTIONAL: ± 1/32"
ANGULAR: MACH ±.5°
BEND ±1°
TWO PLACE DECIMAL: ±.01"
THREE PLACE DECIMAL: ±.005"
FOUR PLACE DECIMAL: ±.0020"
SURFACE FINISH:
ON PART 125 RMS
ON O-RING SURFACES 32 RMS
DIMENSIONING AND TOLERANCING PER ANSI Y14.5M (LATEST)
FINISH:
MATERIAL:
SHOWN

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PRODUCT
DRAWING STATUS

ENERGY RECOVERY INC.
1908 Doolittle Drive, San Leandro, CA 94577
Ph. (510)483-7370 / Fax: (510)483-7371
www.energy-recovery.com

DRAWN	RAC	02/05/2003
CHECKED	TLS	03/18/2003
ENG APPR.	RLS	03/18/2003

THIRD ANGLE PROJECTION

TITLE: ASSY, INTERNALS, PINNED

SIZE C | DWG. NO. 00429 | REV A

SCALE: 0.5:1 | WEIGHT: | SHEET 1 OF 1

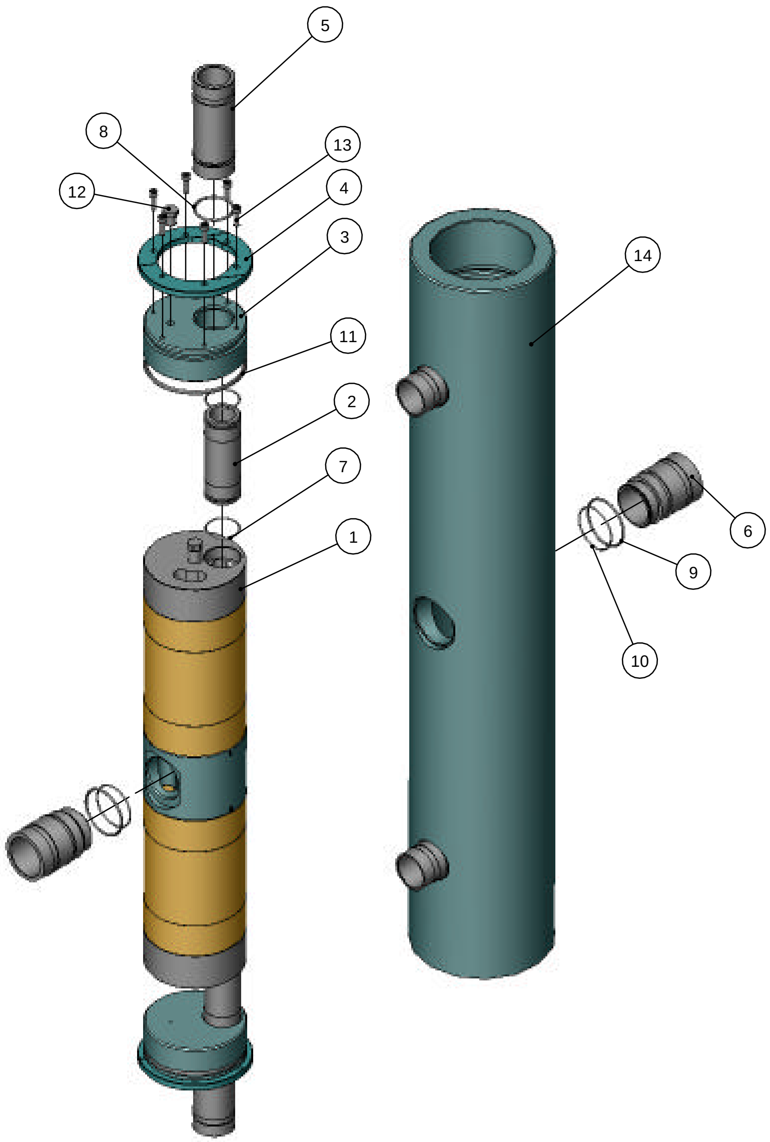
NOTES:
1. SEE ASSEMBLY INSTRUCTIONS FOR PROCEDURES.

00401-090 BILL OF MATERIAL

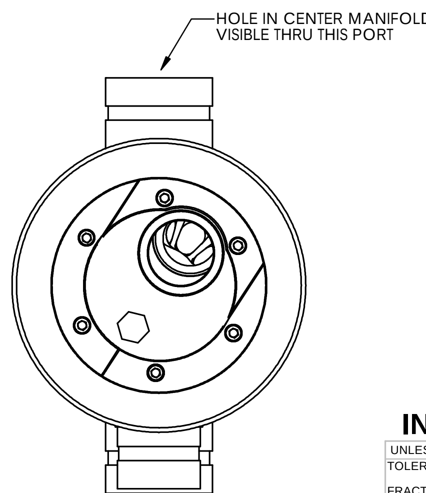
ITEM NO.	QTY.	PART NO.	DESCRIPTION	MATERIAL
1	1	00427-090	ASSY, INTERNALS, DUAL ROTOR, PX-90	---
2	2	00462	NIPPLE, 1 1/4", LOW PRESSURE	PVC
3	2	00440	END CAP, 1 1/2" PORT	FIBERGLASS
4	2	00459	RING, LOCK	FIBERGLASS
5	2	00461	NIPPLE, STRAIGHT, 1 1/2" VIC	AL-6XN
6	2	00463	PORT, SIDE, 2" VIC	AL-6XN
7	4	2-127	O-RING, -127	BUNA-N
8	2	2-223	O-RING, -223	BUNA-N
9	2	2-227	O-RING, -227	BUNA-N
10	2	2-135	O-RING, -135	BUNA-N
11	2	2-347	O-RING, -347	BUNA-N
12	2	20-0051	PLUG, 1/4 NPT, HEX HEAD	PVC
13	12	20-0001	SHCS, 1/4-20 X 5/8" LG	316 SS
14	1	00431-01	VESSEL, PRESSURE ERI, LONG PORT	---

00401-120 BILL OF MATERIAL

ITEM NO.	QTY.	PART NO.	DESCRIPTION	MATERIAL
1	1	00427-120	ASSY, INTERNALS, DUAL ROTOR, PX-120	---
2	2	00462	NIPPLE, 1 1/4", LOW PRESSURE	PVC
3	2	00440	END CAP, 1 1/2" PORT	FIBERGLASS
4	2	00459	RING, LOCK	FIBERGLASS
5	2	00461	NIPPLE, STRAIGHT, 1 1/2" VIC	AL-6XN
6	2	00463	PORT, SIDE, 2" VIC	AL-6XN
7	4	2-127	O-RING, -127	BUNA-N
8	2	2-223	O-RING, -223	BUNA-N
9	2	2-227	O-RING, -227	BUNA-N
10	2	2-135	O-RING, -135	BUNA-N
11	2	2-347	O-RING, -347	BUNA-N
12	2	20-0051	PLUG, 1/4 NPT, HEX HEAD	PVC
13	12	20-0001	SHCS, 1/4-20 X 5/8" LG	316 SS
14	1	00431-01	VESSEL, PRESSURE ERI, LONG PORT	---



TYPICAL ASSEMBLY



WATCH PORT ORIENTATIONS

INCH

UNLESS OTHERWISE SPECIFIED:
TOLERANCES:
FRACTIONAL: ± 1/32"
ANGULAR: MACH ±.5°
BEND ±1°
TWO PLACE DECIMAL: ±.01"
THREE PLACE DECIMAL: ±.005"
FOUR PLACE DECIMAL: ±.0002"
SURFACE FINISH:
ON PART 125 RMS
ON O-RING SURFACES 32 RMS
DIMENSIONING AND TOLERANCING PER ANSI Y14.5M (LATEST)
FINISH:
MATERIAL: SHOWN

REV.	ECN NO.	DESCRIPTION	BY	DATE

REVISIONS

ENERGY RECOVERY INC.
1908 Doolittle Drive, San Leandro, CA 94577
Ph. (510)483-7370 / Fax: (510)483-7371
www.energy-recovery.com

DRAWN	RAC	02/14/2003
CHECKED	TLS	03/18/2003
ENG APPR.	RLS	03/18/2003

THIRD ANGLE PROJECTION

TITLE: ASSY,DUAL ROTOR,ERI, LONG PORT, PINNED

SIZE C | DWG. NO. 00401 | REV A

SCALE: 1:4 | WEIGHT: | SHEET 1 OF 3

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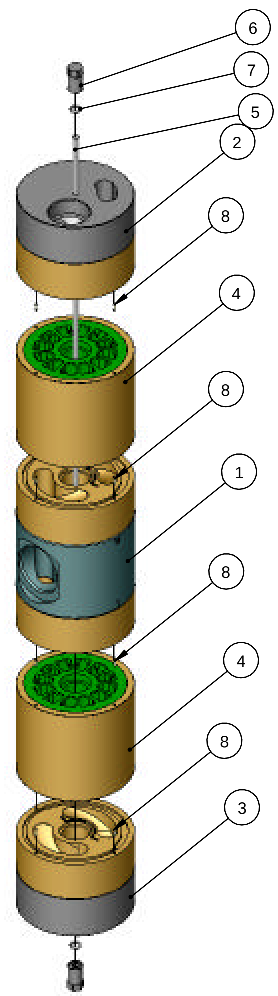
PRODUCT
DRAWING STATUS

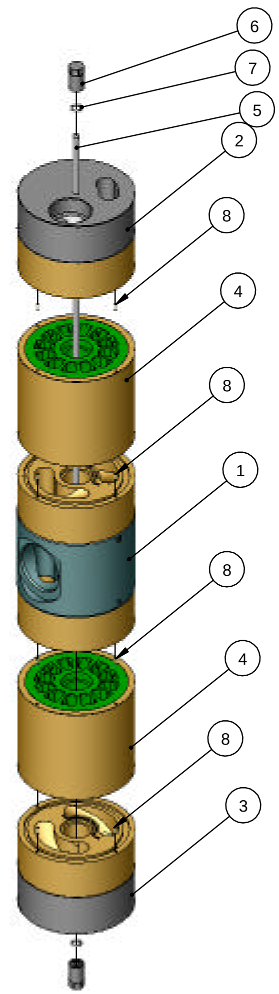
NOTES:
1. SEE ASSEMBLY INSTRUCTIONS FOR PROCEDURES.

ITEM NO.	QTY.	PART NO.	DESCRIPTION	MATERIAL
1	1	00457-090	ASSY, MANIFOLD, CENTER, DUAL ROTOR, PX-90	FIBERGLASS/CERAMIC
2	1	00486-090	ASSY, TOP, DUAL ROTOR, PX-90	FIBERGLASS/CERAMIC
3	1	00496-090	ASSY, ENDCOVER, BTM, DUAL ROTOR, PX-90	FIBERGLASS/CERAMIC
4	2	00400	MATCHED SET, 4.0", ROTOR AND SLEEVE	CERAMIC
5	1	00475	ROD, TENSION, DUAL ROTOR	C-276
6	2	00470	NUT, SEAL, TENSION ROD	AL-6XN
7	2	2-109	O-RING, -109	BUNA-N
8	12	40-0000	DOWEL, 3/32" DIA X 1/4" LG	ACETAL



00427-090

ITEM NO.	QTY.	PART NO.	DESCRIPTION	MATERIAL
1	1	00457-120	ASSY, MANIFOLD, CENTER, DUAL ROTOR, PX-120	FIBERGLASS/CERAMIC
2	1	00486-120	ASSY, TOP, DUAL ROTOR, PX-120	FIBERGLASS/CERAMIC
3	1	00496-120	ASSY, ENDCOVER, BTM, DUAL ROTOR, PX-120	FIBERGLASS/CERAMIC
4	2	00400	MATCHED SET, 4.0", ROTOR AND SLEEVE	CERAMIC
5	1	00475	ROD, TENSION, DUAL ROTOR	C-276
6	2	00470	NUT, SEAL, TENSION ROD	AL-6XN
7	2	2-109	O-RING, -109	BUNA-N
8	12	40-0000	DOWEL, 3/32" DIA X 1/4" LG	ACETAL



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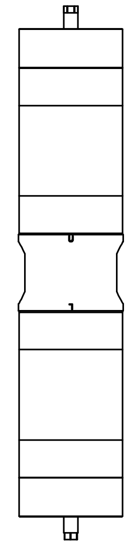

TYPICAL CONFIGURATION
AFTER ASSEMBLY

REV.	ECN NO.	DESCRIPTION	BY	DATE

REVISIONS

INCH

UNLESS OTHERWISE SPECIFIED:
TOLERANCES:
FRACTIONAL: ± 1/32"
ANGULAR: MACH ±.5°
BEND ±1°
TWO PLACE DECIMAL: ±.01"
THREE PLACE DECIMAL: ±.005"
FOUR PLACE DECIMAL: ±.0002"
SURFACE FINISH:
ON PART 125 RMS
ON O-RING SURFACES 32 RMS
DIMENSIONING AND TOLERANCING PER ANSI Y14.5M (LATEST)
FINISH:
MATERIAL:
SHOWN

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PRODUCT
DRAWING STATUS

ENERGY RECOVERY INC.
1908 Doolittle Drive, San Leandro, CA 94577
Ph. (510)483-7370 / Fax: (510)483-7371
www.energy-recovery.com

DRAWN	RAC	02/07/2003
CHECKED	TLS	03/18/2003
ENG APPR.	RLS	03/18/2003

THIRD ANGLE PROJECTION

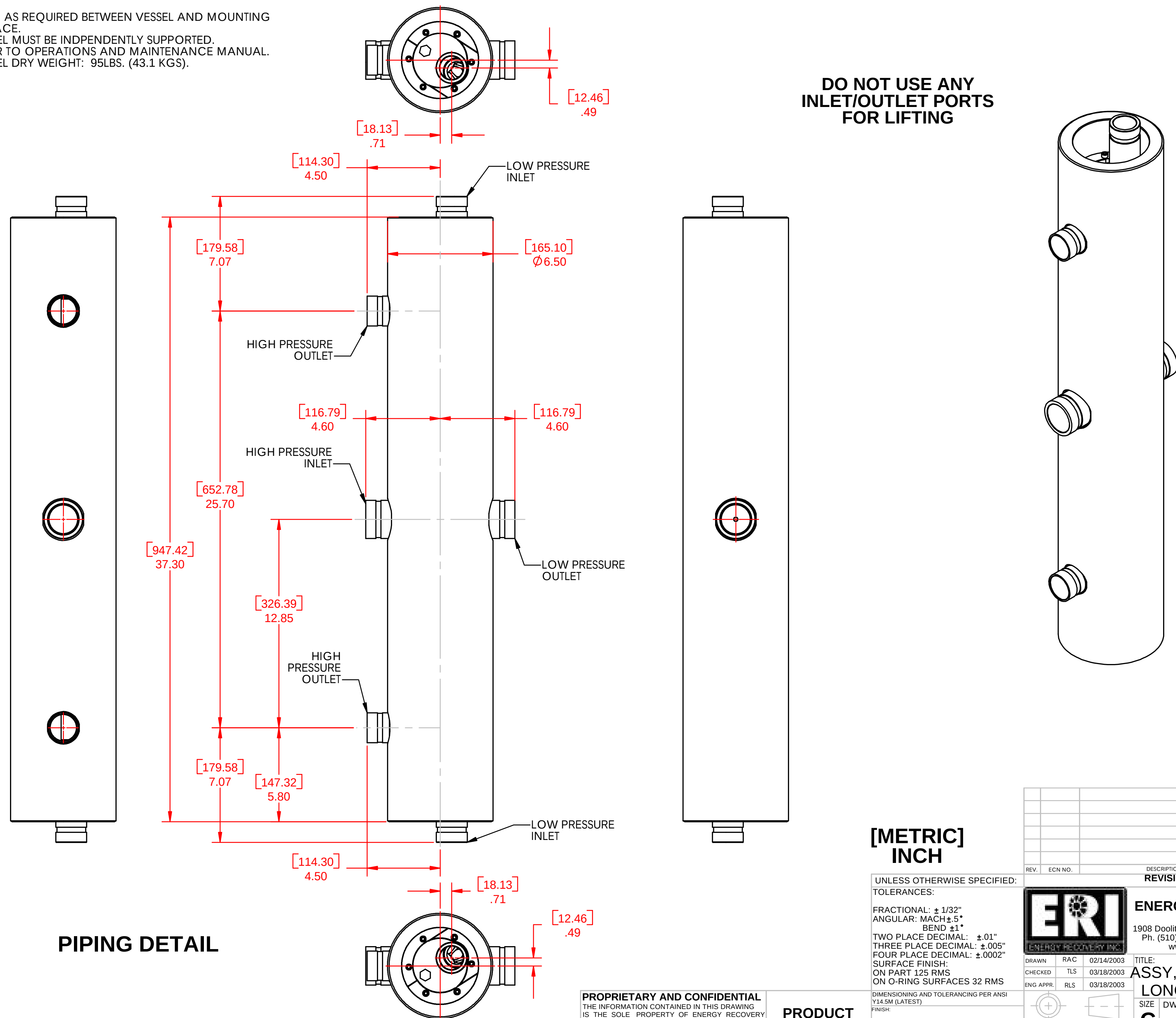
TITLE:
ASSY, INTERNALS, DUAL ROTOR, PINNED

SIZE C | DWG. NO. 00427 | REV A

SCALE: 1:1 | WEIGHT: | SHEET 1 OF 1

NOTES:
1. SHIM AS REQUIRED BETWEEN VESSEL AND MOUNTING SURFACE.
2. VESSEL MUST BE INDPENDENTLY SUPPORTED. REFER TO OPERATIONS AND MAINTENANCE MANUAL.
3. VESSEL DRY WEIGHT: 95LBS. (43.1 KGS).

DO NOT USE ANY INLET/OUTLET PORTS FOR LIFTING



PIPING DETAIL

[METRIC]
INCH

REV.	ECN NO.	DESCRIPTION	BY	DATE

REVISIONS

UNLESS OTHERWISE SPECIFIED:
TOLERANCES:

FRACTIONAL: ± 1/32"
ANGULAR: MACH ±.5°
BEND ±1°
TWO PLACE DECIMAL: ±.01"
THREE PLACE DECIMAL: ±.005"
FOUR PLACE DECIMAL: ±.0002"
SURFACE FINISH:
ON PART 125 RMS
ON O-RING SURFACES 32 RMS

DIMENSIONING AND TOLERANCING PER ANSI Y14.5M (LATEST)
FINISH:
MATERIAL: SHOWN

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www.energy-recovery.com

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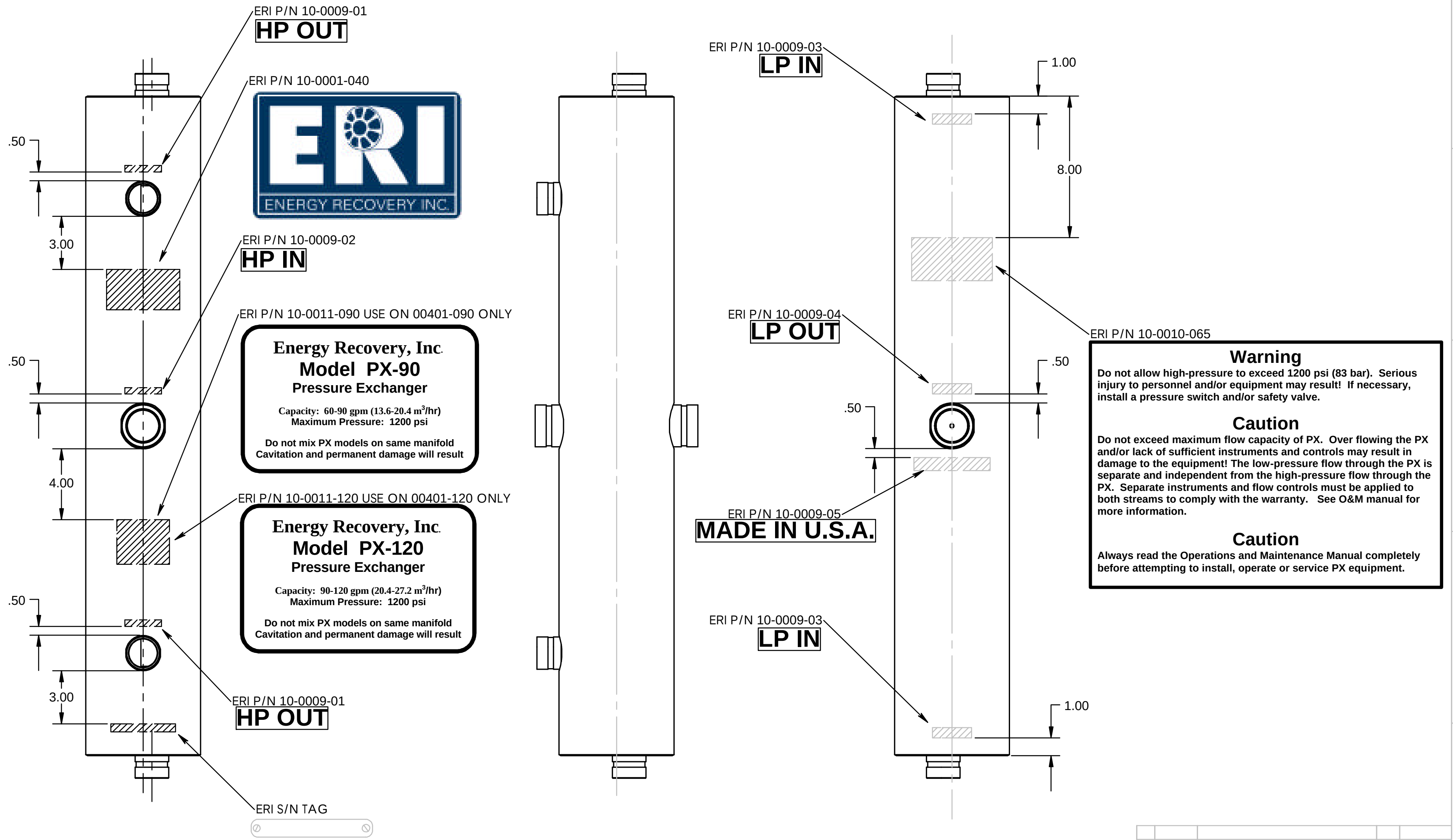
CHECKED	TLS	03/18/2003
ENG APPR.	RLS	03/18/2003

THIRD ANGLE PROJECTION

TITLE: ASSY,DUAL ROTOR,ERI, LONG PORT, PINNED

SIZE	DWG. NO.	REV
C	00401	A

SCALE: 1:4 | WEIGHT: | SHEET 2 OF 3



LABEL LOCATIONS

INCH

UNLESS OTHERWISE SPECIFIED:
TOLERANCES:
FRACTIONAL: ± 1/32"
ANGULAR: MACH ±.5°
BEND ±1°
TWO PLACE DECIMAL: ±.01"
THREE PLACE DECIMAL: ±.005"
FOUR PLACE DECIMAL: ±.0002"
SURFACE FINISH:
ON PART 125 RMS
ON O-RING SURFACES 32 RMS
DIMENSIONING AND TOLERANCING PER ANSI Y14.5M (LATEST)
FINISH:
MATERIAL:
SHOWN

REV.	ECN NO.	DESCRIPTION	BY	DATE

REVISIONS

ENERGY RECOVERY INC.

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www.energy-recovery.com

DRAWN	RAC	02/14/2003
CHECKED	TLS	03/18/2003
ENG APPR.	RLS	03/18/2003

TITLE:
ASSY,DUAL ROTOR,ERI, LONG PORT, PINNED

SIZE	DWG. NO.	REV
C	00401	A

THIRD ANGLE PROJECTION

SCALE: 1:4 WEIGHT: SHEET 3 OF 3

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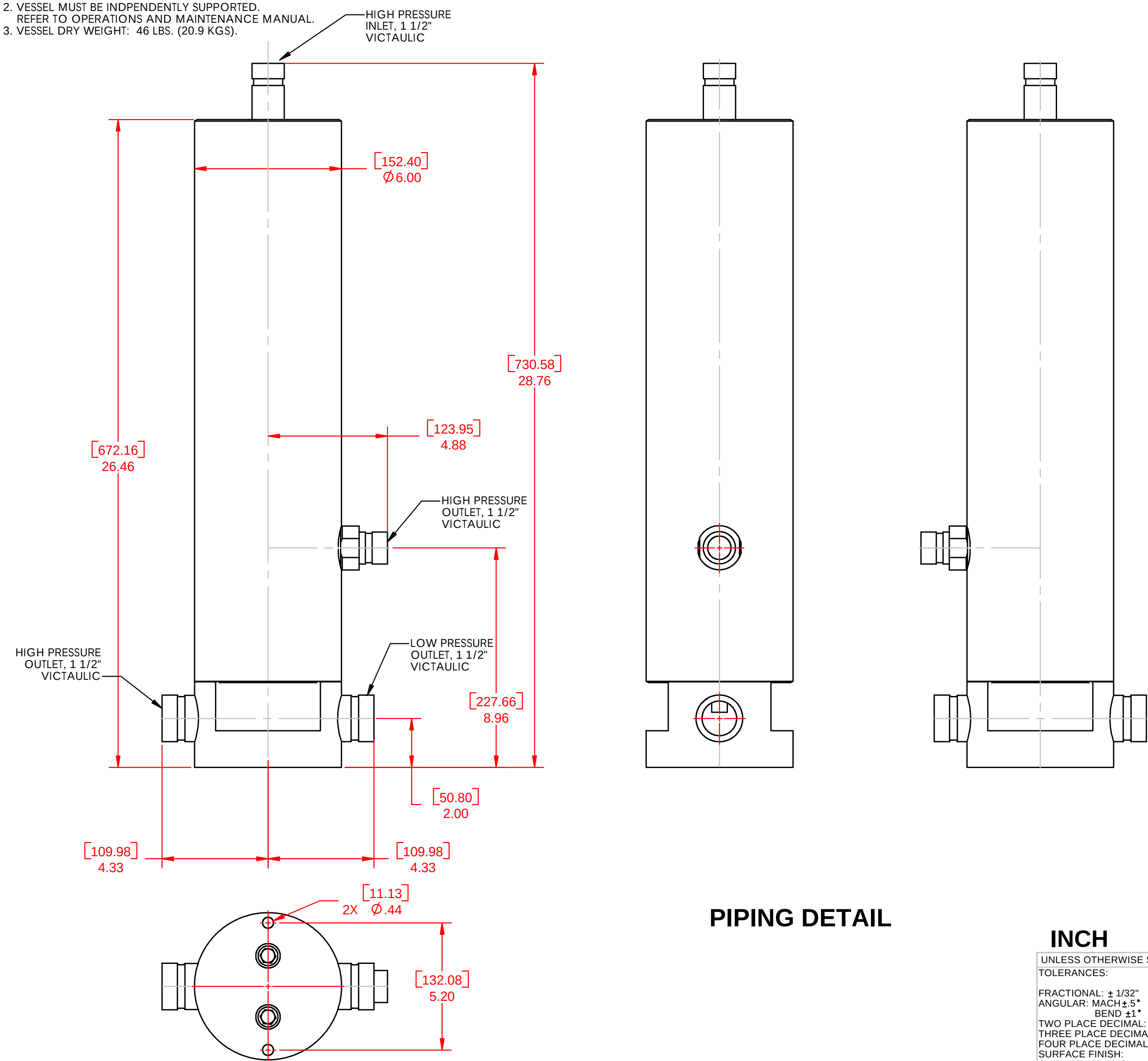
PRODUCT
DRAWING STATUS

NOTES:
1. SHIM AS REQUIRED BETWEEN VESSEL AND MOUNTING SURFACE.
2. VESSEL MUST BE INDPENDENTLY SUPPORTED. REFER TO OPERATIONS AND MAINTENANCE MANUAL.
3. VESSEL DRY WEIGHT: 46 LBS. (20.9 KGS).



DO NOT USE ANY INLET/OUTLET PORTS FOR LIFTING

PIPING DETAIL

INCH

REV.	ECN NO.	DESCRIPTION	BY	DATE

REVISIONS

UNLESS OTHERWISE SPECIFIED:
TOLERANCES:
FRACTIONAL: ± 1/32"
ANGULAR: MACH ±.5°
BEND ±1°
TWO PLACE DECIMAL: ±.01"
THREE PLACE DECIMAL: ±.005"
FOUR PLACE DECIMAL: ±.0002"
SURFACE FINISH:
ON PART 125 RMS
ON O-RING SURFACES 32 RMS

DIMENSIONING AND TOLERANCING PER ANSI Y14.5M (LATEST)
FINISH:
MATERIAL:
SHOWN

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www.energy-recovery.com

DRAWN	RAC	02/05/2003
CHECKED	TLS	03/18/2003
ENG APPR.	RLS	03/18/2003

THIRD ANGLE PROJECTION

TITLE: ASSY, SINGLE ROTOR PINNED

SIZE C | DWG. NO. 00405 | REV A

SCALE: 1:3 | WEIGHT: | SHEET 2 OF 3

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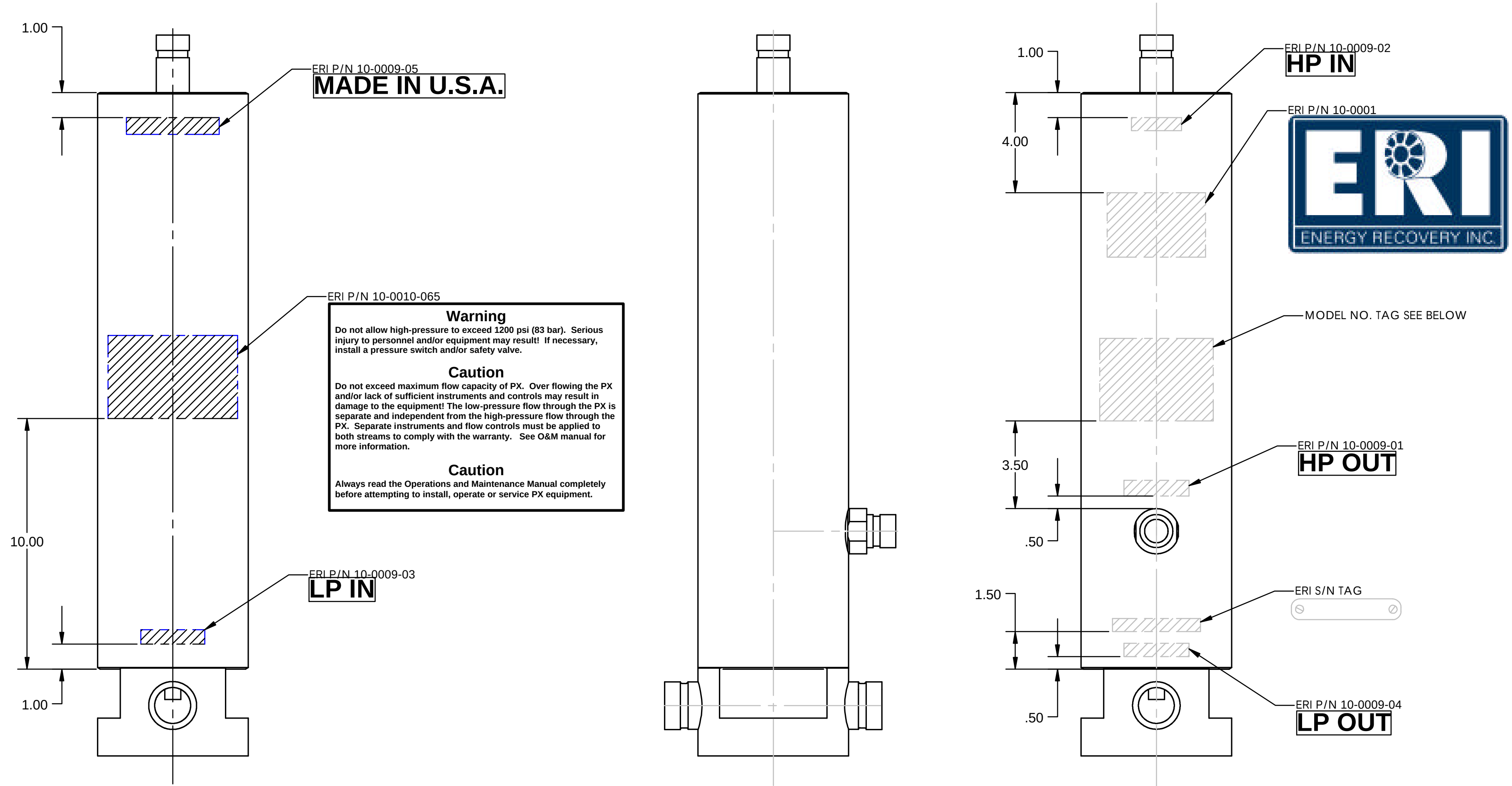
PRODUCT
DRAWING STATUS



LABEL LOCATIONS

MODEL NUMBER TAGS:

ERI P/N 10-0011-015 USE ON 00405-015

Energy Recovery, Inc.
Model PX-15
Pressure Exchanger
Capacity: 10-15 gpm
Maximum Pressure: 1200 psi
Do not mix PX models on same manifold
Cavitation and permanent damage will result

ERI P/N 10-0011-025 USE ON 00405-025

Energy Recovery, Inc.
Model PX-25
Pressure Exchanger
Capacity: 15-25 gpm
Maximum Pressure: 1200 psi
Do not mix PX models on same manifold
Cavitation and permanent damage will result

ERI P/N 10-0011-040 USE ON 00405-040

Energy Recovery, Inc.
Model PX-40
Pressure Exchanger
Capacity: 25-40 gpm
Maximum Pressure: 1200 psi
Do not mix PX models on same manifold
Cavitation and permanent damage will result

ERI P/N 10-0011-060 USE ON 00405-060

Energy Recovery, Inc.
Model PX-60
Pressure Exchanger
Capacity: 40-60 gpm
Maximum Pressure: 1200 psi
Do not mix PX models on same manifold
Cavitation and permanent damage will result

INCH

UNLESS OTHERWISE SPECIFIED:
TOLERANCES:
FRACTIONAL: ± 1/32"
ANGULAR: MACH ± .5°
BEND ± 1°
TWO PLACE DECIMAL: ± .01"
THREE PLACE DECIMAL: ± .005"
FOUR PLACE DECIMAL: ± .0002"
SURFACE FINISH:
ON PART 125 RMS
ON O-RING SURFACES 32 RMS
DIMENSIONING AND TOLERANCING PER ANSI Y14.5M (LATEST)
FINISH:
MATERIAL:
SHOWN

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PRODUCT
DRAWING STATUS

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www.energy-recovery.com

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CHECKED	TLS	03/18/2003
ENG APPR.	RLS	03/18/2003

THIRD ANGLE PROJECTION

TITLE: ASSY, SINGLE ROTOR PINNED

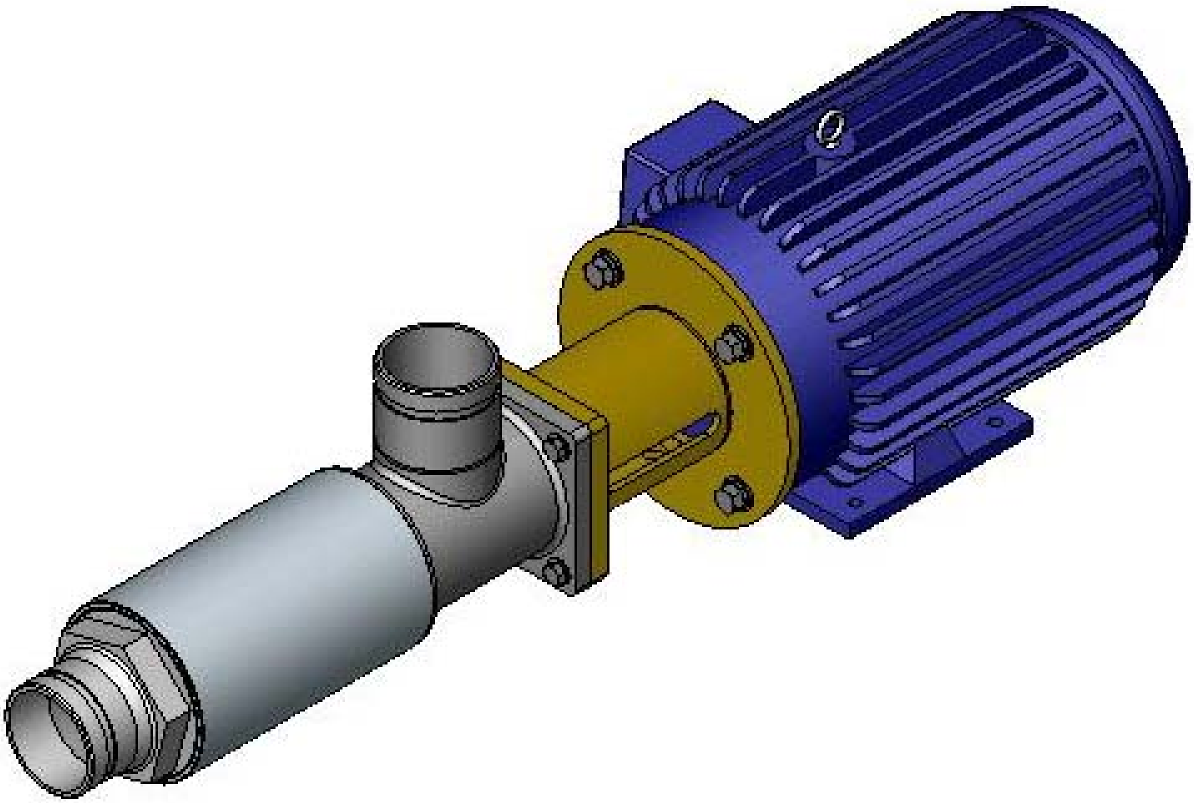
SIZE C | DWG. NO. 00405 | REV A

SCALE: 1:3 | WEIGHT: | SHEET 3 OF 3

Appendix D

PX Booster Pumps

ENERGY RECOVERY, INC.



INSTALLATION, OPERATION, & MAINTENANCE MANUAL

Series 8500-2400 PX Booster Pumps

Energy Recovery, Inc.
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Installation, Operation, & Maintenance Manual
Series 8500-2400 PX Booster Pumps

TABLE OF CONTENTS

1.0 INTRODUCTION

This manual contains instructions for the installation, operation, and maintenance of the Energy Recovery, Inc.™ (ERI™) PX Booster Pumps for energy recovery in Sea Water Reverse Osmosis (SWRO) systems in conjunction with ERI's Pressure Exchanger™ (PX™) technology. The PX Booster Pump boosts the pressure in the high pressure portion of an SWRO system to make up the small pressure losses that occur through the SWRO membranes, the PX units and the associated piping. The PX Booster Pump is designed to withstand a high inlet pressure in a corrosive seawater environment.

Please read this manual thoroughly before installation or 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. PX and PX Booster Pump maintenance personnel are strongly encouraged to attend Factory Training courses offered by Energy Recovery, Inc. Energy Recovery, Inc. technical service personnel are available for assistance by telephone during the regular business hours of 08:00 to 17:00 Pacific Standard Time. Field service and system commissioning assistance are available.

Further information about PX Booster Pumps or other Energy Recovery, Inc. products or service can be found by contacting Energy Recovery, Inc. at:

Energy Recovery, Inc.
1908 Doolittle Drive, San Leandro, CA 94577 USA
Tel: +1 510 483 7370 / Fax: +1 510 483 7371
www.energy-recovery.com / sales@energy-recovery.com

2.0 MATERIALS OF CONSTRUCTION AND QUALITY

ERI's commitment to quality starts with the fabrication and procurement of top quality materials made to extremely tight clearances. Every part is checked to ensure it meets all dimensional specifications during and after each stage of the manufacturing process. All wetted metal components in PX Booster Pumps are AL6XN® or equivalent stainless steel. Impellers and diffusers are fiber reinforced polymer. The mechanical seal has carbide contact/sealing faces. Seals are ethylene propylene (EPDM).

Assembled PX Booster Pump units are subjected to extensive testing in our wet test facility. Each PX Booster Pump is tested for efficiency, operating pressures, and flow rates. Each unit is tracked with a serial number and the testing records are maintained.

3.0 SAFETY, ARRIVAL AND INSPECTION

The PX Booster Pump has been designed to provide safe and reliable service. However, it is both a pressure vessel and a piece of industrial rotating machinery. Therefore, operations and

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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 PX Booster Pump.

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.

Each PX Booster Pump should be inspected immediately upon arrival and any irregularities due to shipment should be reported to the carrier. PX Booster Pump units are securely packed with plugs in the fittings to protect the unit from damage during transportation. Care must be taken during unpacking and handling to avoid damage to the PX Booster Pump.

CAUTION	When handling and installing a PX Booster Pump, 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 Booster Pump by the port fittings.

4.0 PRINCIPLE OF OPERATION

The PX Booster Pump is designed to be used in SWRO systems in conjunction with ERI's PX technology. The PX Booster Pump is a horizontal multistage centrifugal pump driven by a Totally Enclosed Fan Cooled (TEFC) motor. The PX Booster Pump boosts the pressure in the high pressure portion of an SWRO system to make up the small pressure losses that occur through the SWRO membrane, the PX units and the associated piping. The PX Booster Pump is designed to withstand a high inlet pressure in a corrosive seawater environment.

Figure 4-1 shows the flow path of a PX Booster Pump installed in a typical SWRO system equipped with PX technology. The reject brine from the SWRO membranes (G) passes through the PX unit(s) where its pressure is transferred directly to a portion of the incoming raw seawater at up to 95% efficiency. This pressurized seawater stream (D), which is nearly equal in volume and pressure to the reject stream, passes through the PX Booster Pump (not the main high-pressure pump) to add the small amount of pressure lost to friction in the PX unit(s), the membranes, and the associated piping. The PX Booster Pump is specially designed to handle high operating pressures while consuming minimal energy to provide a small boost to the high-pressure flow. The PX Booster Pump also serves to drive the flow of the high-pressure stream through the PX unit(s) (G and D). Fully pressurized seawater then merges with the main seawater to the SWRO system after the main high-pressure pump. Example flow rates and pressures are listed in Table 4.1.

Figure 4-2. Typical SWRO System with PX Unit(s) and PX Booster Pump

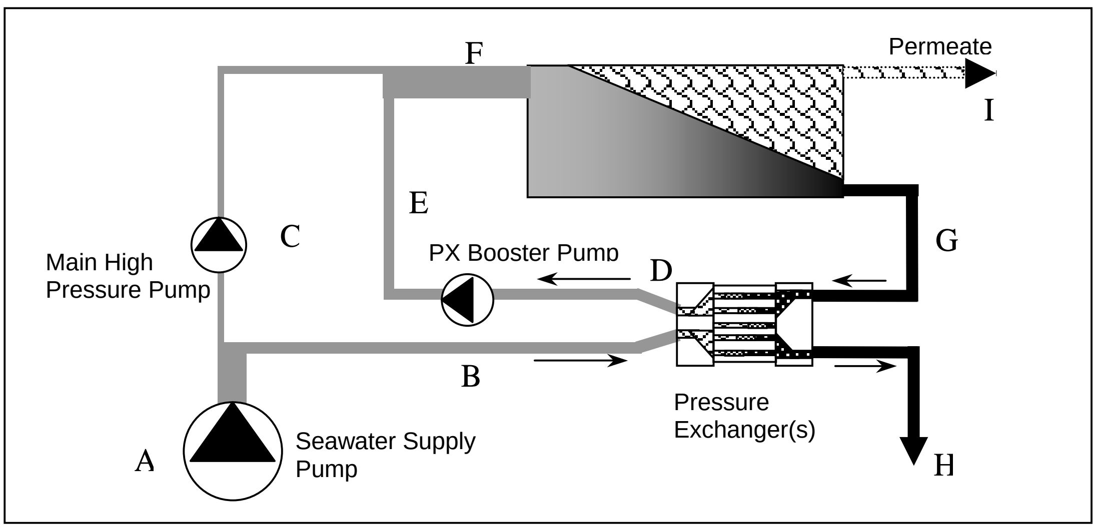


Table 4-1 - Example Flow Rates and Pressures

STREAM	DESCRIPTION	FLOW RATE	PRESSURE PSI / BAR
A	Seawater supply	330	29 / 2.0
B	PX LP Inlet/ Seawater	195	29 / 2.0
C	Main HP Pump outlet	135	1000 / 69
D	PX HP Outlet/ Seawater	195	957 / 66
E	Booster Pump Outlet/ Seawater	195	1000 / 69
F	SWRO Feed Stream	330	1000 / 69
G	PX HP Inlet/ Reject	200	971 / 67
H	PX LP Outlet/ Reject	200	15 / 1.0
I	SWRO Product Water	130	5 / 0.3

In an SWRO system equipped with PX technology, the main 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 technology significantly reduces flow through the main pump. This point is significant because a reduction in the size of the main pump results in lower operating costs. In a typical SWRO system equipped with PX technology, the main pump will provide 41% of the energy, the booster will provide 2% and the PX unit(s) will provide the remaining 57%. Since the PX energy recovery device uses no external power, the total power savings is 57% compared to a system with no energy recovery.

It is important to note that the PX unit(s) and associated boost pump are sized for 100% of the reject flow. The role and size of the main high-pressure pump is reduced to that of a "make-up pump" to compensate for the water that is exiting the SWRO system as permeate.

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

5.0 INSTALLATION

The PX Booster Pump should be installed in a dry, sheltered location. Some type of drainage should be provided beneath the pump to allow standing water to drain when performing maintenance or repair. See installation drawings in Section 13.0 for pump dimensions, interface locations and minimum maintenance envelope requirements.

1. Place the PX Booster Pump in an appropriate location and mount the motor securely; making sure that the base of the unit is permanently supported.
2. Connect the inlet and outlet of the pump to the appropriate points. Proper piping, piping support, and motor mounts must be implemented to minimize external stresses on all piping fittings. Flexible couplings should be used for joining fittings and piping. See Section 13.0 for appropriate connection dimensions and specifications. PX Booster Pumps are shipped with the inlet oriented vertically upward. The inlet housing can be rotated either left or right to a horizontal orientation. Remove the four (4) bolts that connect the inlet housing to the yellow bell housing, rotate the pump head and replace the bolts. Torque bolts to 12 ft-lbs (16 N-m) as shown in Figure 7-4 below.

CAUTION The PX Booster Pump is constructed from AL6XN or equivalent stainless steel. Inlet and discharge interconnecting lines should be constructed of suitable materials to avoid galvanic corrosion.

3. Connect the pump motor to a suitable electrical supply. See the motor plate or the inside cover of the motor electrical junction box for high and low voltage wiring diagrams. If no wiring diagram is evident on the motor, refer to Table 5-1. Connect a suitable ground to the pump motor.

4. The SWRO-PX system must include pressure gauges upstream and downstream of the PX Booster Pump and a high-pressure flow meter in the high-pressure circuit.

Table 5-1 – Motor Wiring

MOTOR MANUFACTURER		L1	L2	L3	JOIN
General Electric	High Voltage	1	2	3	4+7, 5+8, 6+9
	Low Voltage	1+7	2+8	3+9	4+5+6
Leeson	High Voltage	1+12	2+10	3+11	4+7, 5+8, 6+9
	Low Voltage	1+6+7+12	2+4+8+10	3+5+9+11	—

DANGER

Disconnect electrical supply before installing and/or servicing the pump. Failure to do so can cause serious injury or death to personnel.

CAUTION

Strictly observe all applicable electrical codes and regulations governing the installation and wiring of electrical equipment.

CAUTION

Piping must be independently supported. Do not allow piping to place a load on the PX Booster Pump.

NOTE

The power supply should always be of a greater service rating than the requirements of the pump. Never connect the pump to a line that services another electrical device. The pump should have dedicated power circuit with proper fuse or breaker protection.

NOTE

The PX Booster Pump is designed to be used in conjunction with a variable frequency drive and high-pressure flow meter.

NOTE

Check for proper motor rotation upon start up.

6.0 OPERATION

6.1 Specifications

The successful use of the PX Booster Pump depends on observing some basic operating conditions and precautions. The PX Booster Pump 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.

6.1.1 System Performance Specifications

Table 6-1 provides a summary of system performance specifications. See Section 12.0 for flow and pressure curves.

Table 6-1 - System Performance Specifications

Parameter	Specification
Raw Water Temperature Range:	33-113°F (1-43°C)
Maximum Outlet Pressure:	1200 psi / 83 bar
Minimum Inlet Pressure:	15 psi / 1.0 bar
Design Flow Range: *	
HP-8503	30-110 gpm (7 – 25 m3/hr)
HP-8504	30-110 gpm (7 – 25 m3/hr)
HP-1253	40-190 gpm (9 – 43 m3/hr)
HP-1254	40-190 gpm (9 – 43 m3/hr)
HP-2402	80-300 gpm (18 – 68 m3/hr)
HP-2403	80-300 gpm (18 – 68 m3/hr)

* 60 Hz / 3450 rpm

6.1.2 Precautions and Conditions

The following precautions / conditions apply:

- Piping connections to the pump must be designed so as not to induce stress on the pump or motor.
- Ensure that all flexible connections are secure and tight before operating pump.
- Under no circumstances shall the inlet pressure or outlet pressure exceed 1,200 psig (83 bar).
- Ensure sufficient feed water supply. The PX Booster Pump should be thoroughly purged of air before startup. Operating the PX Booster Pump with feed pressures less than 15 psi may result in damage to PX Booster Pumps internal components. Never run pump dry.

DANGER

Do not allow the high-pressure reject and/or seawater 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).

CAUTION

Allowable operating ranges for individual PX Booster Pumps are listed in Table 6-1. PX Booster Pumps are not designed to operate outside of these ranges.

6.1.4 Physical Characteristics

See Section 13.0 for weights and dimensions. Connections dimensions and requirements are provided in Table 6-2.

Table 6-2 - Connection Dimensions and Requirements

Utility	Connection	Maximum Pressure (psi / bar)
Inlet	3” Flexible Coupling	1,200 / 83
Discharge	3” Flexible Coupling	1,200 / 83

6.1.5 Utility Requirements

Power requirements are provided on the nameplate on the top of all PX Booster Pump motors. Horsepower requirements are provided in Table 6-3.

Table 6-3 – Motor Horsepower Requirements

HP-8503	HP-8504	HP-1253	HP-1254	HP-2402	HP-2403
5	7.5	10	15	15	20

6.1.6 Spare Parts

A listing of recommended ERI spare parts is provided in Table 6-4. O-ring kits are recommended for disassembly and inspection. Rebuilt kits provide impellers, stage assemblies and O-rings.

Table 6-4 - Recommended Spare Parts

DESCRIPTION	QTY	O-RING KIT PART NUMBER	REBUILD KIT PART NUMBER	MECHANICAL SEAL KIT
HP-8503	1	20005-02	20005-01*	20004-01
HP-8504	1	20006-02	20006-01*	20004-01
HP-1253	1	20007-02	20007-01*	20004-01
HP-1254	1	20008-02	20008-01*	20004-01
HP-2402	1	20009-02	20009-01*	20004-01
HP-2403	1	20010-02	20010-01*	20004-01

* Includes Impellers, Stage Assemblies and O-rings

NOTE

Only genuine ERI spare parts should be used in PX Booster Pumps. Use of parts other than those specified by ERI will void the warranty.

6.2 Startup Procedure

Refer to the PX Operations and Maintenance manual for detailed startup and shutdown instructions for the PX device.

1. Verify system is de-energized and un-pressurized.
2. Check tightness of all lines and fittings.
3. Supply feed water to the SWRO system and the PX unit’s low-pressure inlet.

4. Verify that the inlet pressure to the PX Booster Pump is at least 15 psi as seen at the inlet of the main high-pressure pump. Verify that all air has been purged from the system. The pump cannot be run dry for even a few seconds. Damage will occur in seconds if the pump is started dry.

CAUTION	Never run the PX Booster Pump dry or with low feed flow. Operating with feed pressures less than 15 psi (1 bar) or below recommended the flow range can cause damage to the pump's internal components.

5. Jog the PX Booster Pump and verify that its rotation is correct.

NOTE	The PX Booster Pump should rotate in the clockwise direction when facing the rear of the motor.

6. Start the PX Booster Pump and verify that the pump is operating on the flow and pressure curves provided in Section 12.0.

6.3 Maintenance and Startup Log

A sample operating-log has been provided in Section 8.0 of this manual and must be submitted by fax or e-mail to Energy Recovery, Inc. in San Leandro, California upon completion of the startup and flow balancing routines. ERI requests submittal of this form with the initial startup data within 24 hours of startup. The data must be recorded daily and maintained during the life of the warranty in order to support any claims. Include pump serial number with all submittals.

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. upon completion of the startup and balancing routines. The data must be recorded daily and maintained during the life of the warranty in order to support any claims. Include serial number with submittal.

7.0 MAINTENANCE INSTRUCTIONS

7.1 General

The table below details the specific recommended pump maintenance requirements for the ERI's PX Booster Pump product line:

Table 7-1 - Periodic Maintenance Task Frequency

	Weekly	3 Months	As Required	Labor Hours (approximate)
Inspect connections	•			0.1
Inspect mechanical seal	•			0.1
Lubricate pump motor		•		0.2
Change mechanical seal			•	2.0

7.2 Lubricate PX Booster Pump Motor

Motor bearings should be checked daily for temperature and noise. Motor bearings must be lubricated a minimum of every three months. Use a grease gun and high-quality ball bearing grease such as Shell Dolium R or Chevron SR1 2. Refer to the motor manufacturer's websites for additional guidance and information.

7.3 Mechanical Seal Maintenance

A mechanical seal is used to seal the rotating shaft. This seal will require replacement approximately every 12-18 months. An indication that maintenance is required will be a leak or drip from the rear of the pump into the bell housing. Mechanical seal kits are available from ERI. The kit includes the components listed in Table 7-2 and illustrated in Figure 7-1.

Table 7-2 - Mechanical Seal Kit - ERI Part Number 20004-01

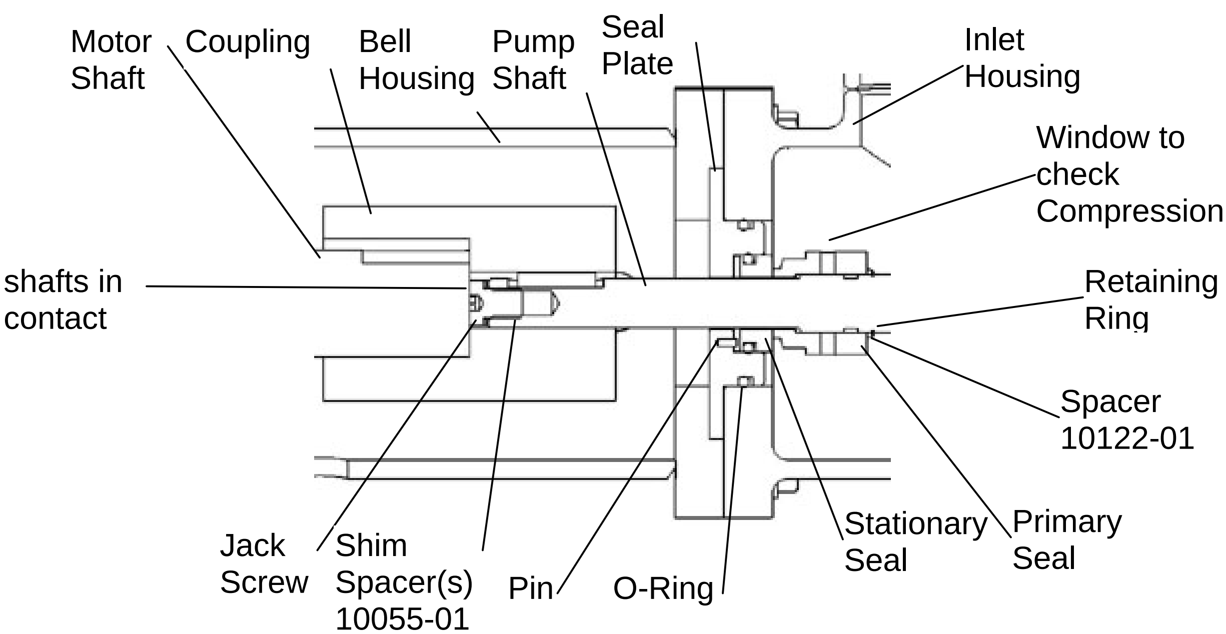
PART NUMBER	DESCRIPTION	QUANTITY
10055-01	SHIM	2
10066-01	RETAINING RING, 3 /4"	1
10117-01	DOWEL PIN	2
10122-01	SPACER	1
10123-01	MECHANICAL SEAL	1
10124-01	FENDER WASHER	2
10128-01	ALLEN WRENCH, 3/32"	1
10134-01	THREAD LOCKER	1
10160-01	O-RING, -225	1
80027-01	MECHANICAL SEAL O&M MANUAL	1

ERI offers a tool kit (ERI Part Number 20003-01) for PX Booster Pump maintenance operations. Alternately, a list of tools and materials recommended for maintenance of the mechanical seal are provided in Table 7-3.

Table 7-3 - Recommended Tools and Materials

Pump Model	Tool	Application
all	9/16-inch Wrench	Bolts between Inlet Housing and Bell Housing
all	3/4-inch Wrench	Bolts between Bell Housing and Motor
8500-pumps	3/16-inch Allen/Hex Wrench	Coupling
1250- and 2400-pumps	1/4-inch Allen/Hex Wrench	Coupling
all	3/32-inch Allen/Hex Wrench	Seal Set Screws
all	Anti-Seize Compound	All Threads
all	Water Soluble Lubricant	O-Rings

Figure 7-1 - Section View of Shaft and Seal Components



The following procedure provides instructions for removing an old seal and inserting a new one.

7.3.1 Remove the Old Mechanical Seal

1. Verify system is de-energized and un-pressurized.
2. Disconnect the flexible coupling connections from the inlet and outlet of the PX Booster Pump and allow water to drain from system.
3. Unbolt the motor base from the floor.
4. Stand the PX Booster Pump on the motor in a vertical orientation as shown in Figure 7-2.
5. Partially loosen (1-3 turns) the eight (8) shaft coupling screws inside the bell housing. There is an access slot for these screws at the side of the bell housing. See Figure 7-3.
6. Remove the four bolts that hold the inlet housing to the bell housing with a 9/16” wrench as shown in Figure 7-4.

Figure 7-2 - Pump Oriented Vertically

Figure 7-3 - Loosen Coupling Screws

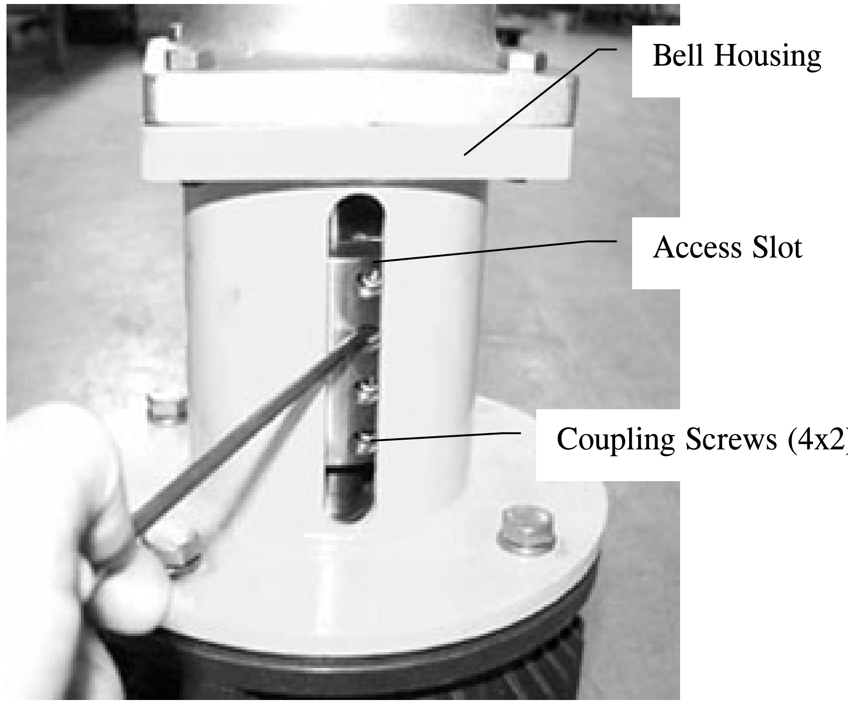


Figure 7-4 - Remove Pump from Bell Housing

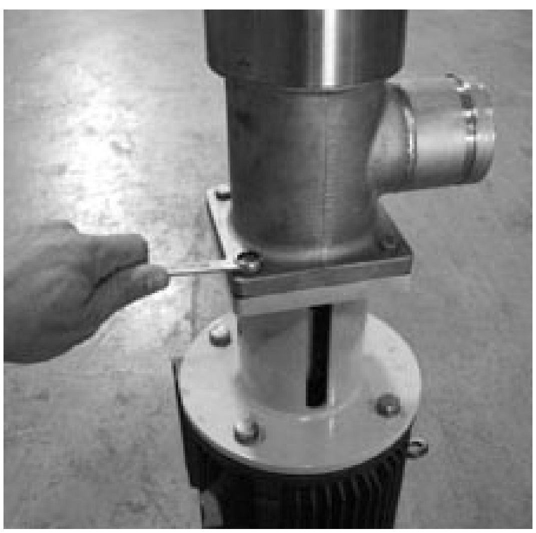
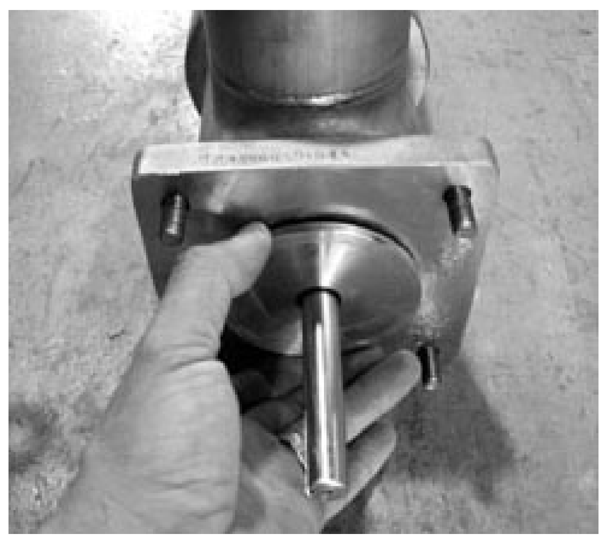


Figure 7-5 - Remove Seal Plate from Inlet



7. Pull the pump, shaft and seal out of the bell housing and away from the motor.
8. Remove the seal plate from the inlet housing as shown in Figure 7-5. It may be necessary to pull on the pump shaft to create an initial gap between the seal plate and the inlet.
9. The mechanical seal includes the primary seal and the stationary or mating plate as shown in Figure 7-6. Extract the stationary plate from the seal plate by pushing through the seal plate with a rod as shown in Figure 7-7. Remove stationary plate from the seal plate.

Figure 7-6 - Mechanical Seal Components

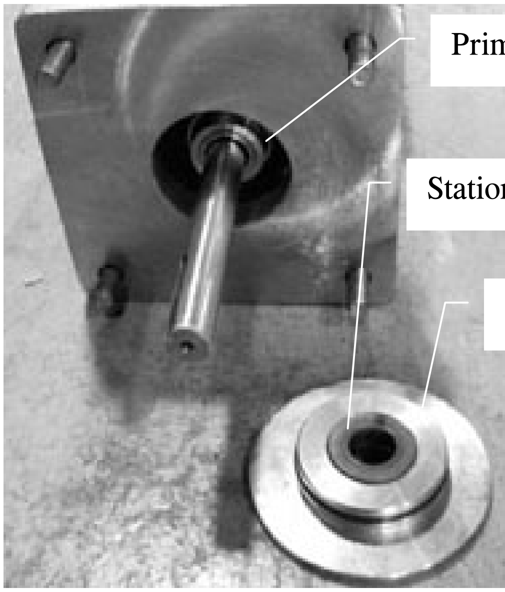
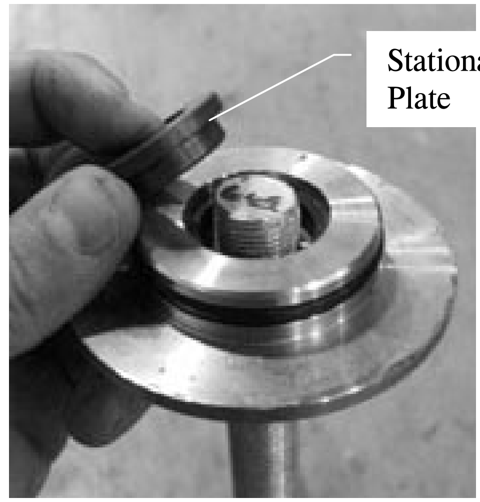


Figure 7-7 - Extract Stationary Plate from Seal Plate



10. Loosen the four (4) set screws (3/32 inch hex) that hold the primary seal onto the shaft as shown in Figure 7-8. Be careful not to strip the set screws. If a particular set screw is very tight, it may be necessary to rotate the shaft and loosen a different set screw first.

Figure 7-8 - Loosen Set Screws

11. Slide the primary seal off the shaft and out of the pump.
12. Remove the bell housing from the motor as shown in Figure 7-9.
13. Remove the coupling from the motor shaft. Disassemble the coupling as shown in Figure 7-10. Clean the coupling and the shaft keys to remove any salt deposits or debris.

CAUTION

Keep the shafts and coupling clean and free of dirt, rust and foreign matter. Use plenty of anti-seize upon reassembly to ensure easy disassembly the next time.

Figure 7-9 - Remove Bell Housing

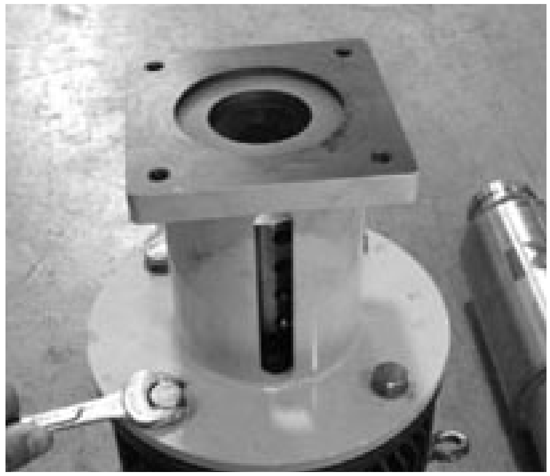
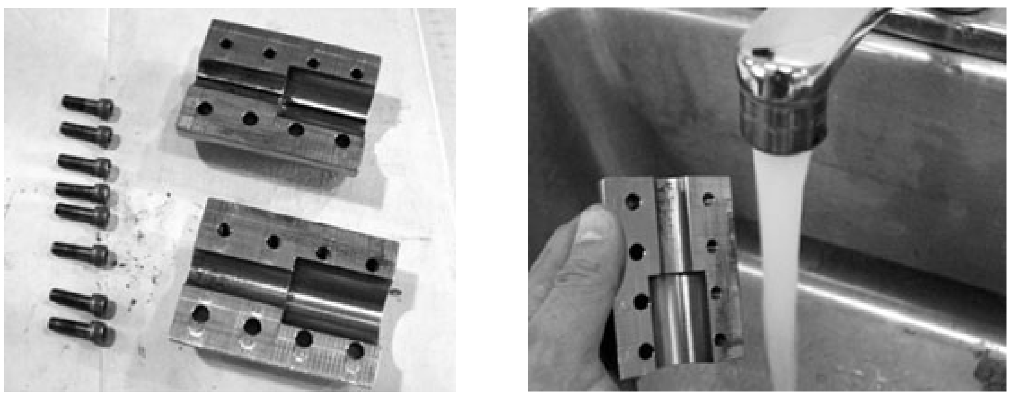


Figure 7-10 - Disassemble Coupling and Clean Components

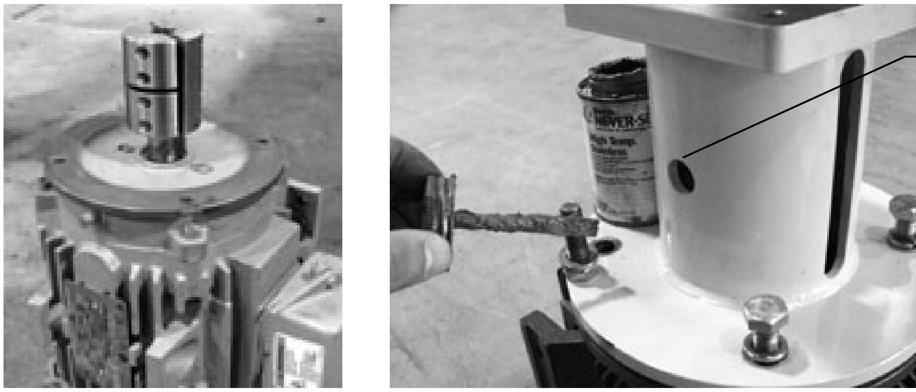


7.3.2 Install the New Mechanical Seal

Before installing the new mechanical seal, completely remove the pump head, the bell housing and the coupling as described above.

1. Reassemble the coupling using plenty of antiseize on the bolts and inside of the coupling. Apply antiseize to the motor shaft.
2. Install the coupling onto the motor shaft as shown in Figure 7-11. Use plenty of antiseize.
3. Install the bell housing onto the motor as shown in Figure 7-11. Use anti-seize compound on the bolt threads. Make sure that the drainage hole is oriented so that it will be on the bottom of the bell housing when the PX Booster Pump is reinstalled. Torque the bolts to 40 foot-pounds (ft-lbs) / 58 N-m.

Figure 7-11 – Install Coupling and Bell Housing onto Motor



4. Lubricate the o-ring in the new primary seal with a water-soluble lubricant. Install new spacer ring and new primary seal onto the pump shaft. Slide these components onto the shaft until they contact the retaining ring. See Figure 7-12 and 7-13 for the correct sequence. Tighten the three set screws to 7 inch-pounds (in-lbs) / 0.79 Newton-meters (N-m) torque using a 3/32-inch hex wrench.

Figure 7-12 - Primary Seal Sequence

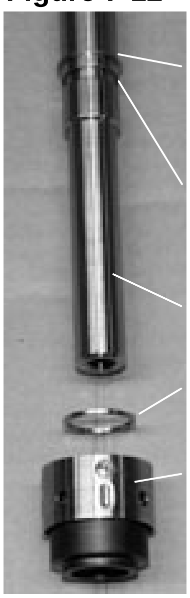
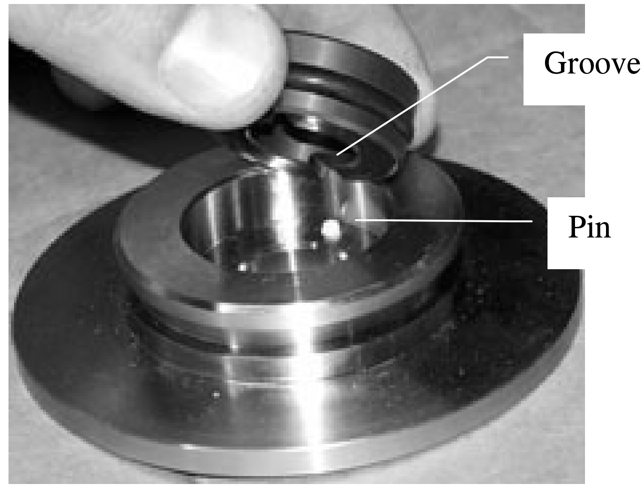


Figure 7-13 - Primary Seal Assembly

5. Insert the anti-rotation pin into the seal plate as shown in Figure 7-14. Once inserted, the pin should not protrude more than 1/16-inch (1.6 mm). Assure that there is no debris inside the seal plate that would prevent the stationary seal from fully seating.
6. Lubricate the O-ring of the new stationary seal with a water-based lubricant such as glycerin or soap. Insert the new stationary seal into the seal plate. Be sure to line up the groove in the bottom of the stationary ring with the anti-rotation pin as shown in Figure 7-15. The stationary seal must seat flat and level in the seal plate.

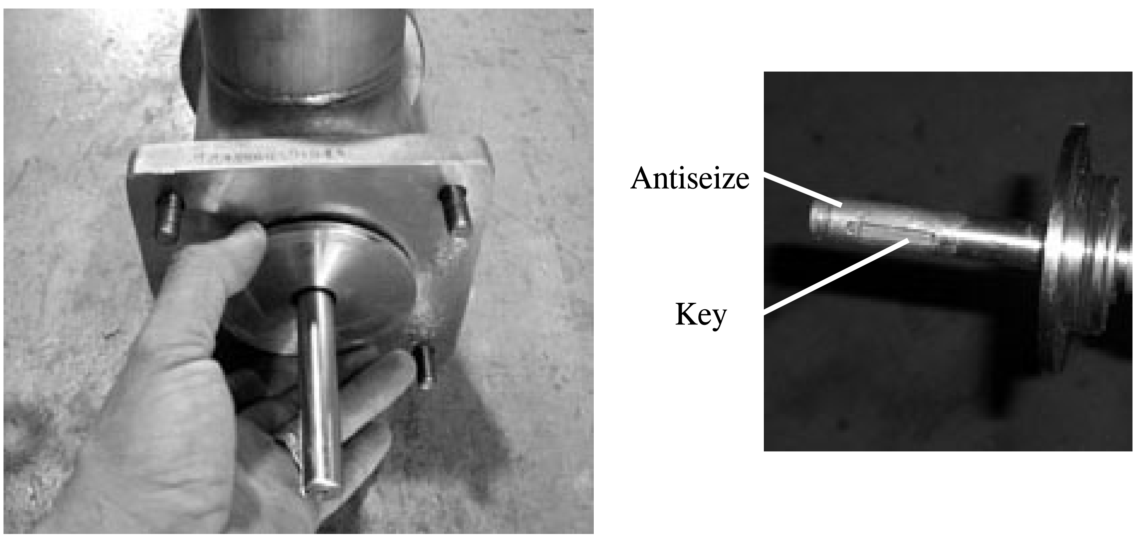
Figure 7-14 - Insert Anti-Rotation Pin

Figure 7-15 - Stationary Seal, Line up Pin with Groove



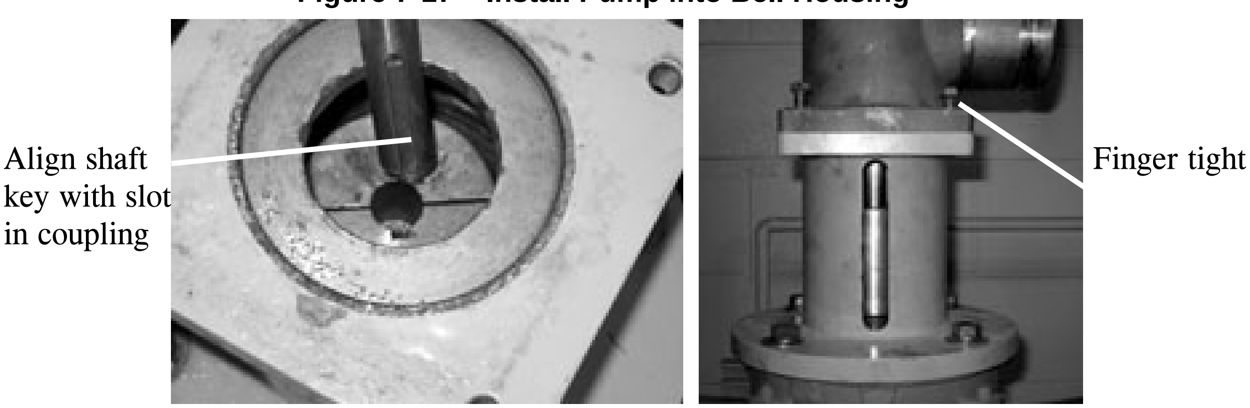
7. Slide the seal plate onto the shaft as shown in Figure 7-16.

Figure 7-16 – Assemble the Shaft, Seal and Seal Plate, Install into Inlet Housing



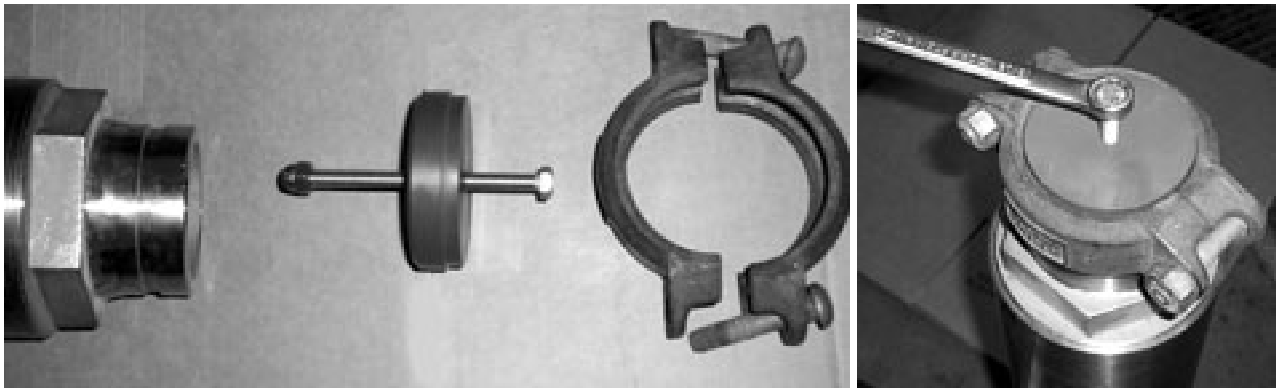
8. Align the shaft key with the slot in the coupling and install the pump onto the bell housing as shown in Figure 7-17.

Figure 7-17 – Install Pump into Bell Housing



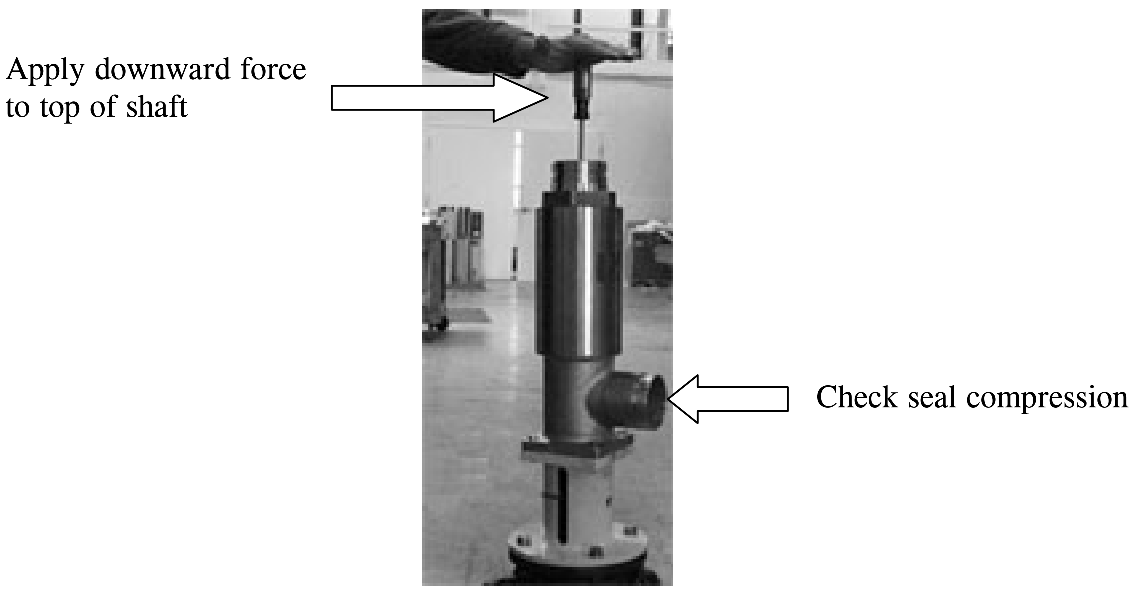
9. Assemble the seal compression tool components using a flexible coupling as shown in Figure 7-18. Alternately, compress seal manually as shown in Figure 7-19.

Figure 7-18 – Assemble and Install Seal Compression Tool Components



10. Check the seal compression by applying downward force on the pump shaft while looking into the inlet housing as shown in Figure 7-19.

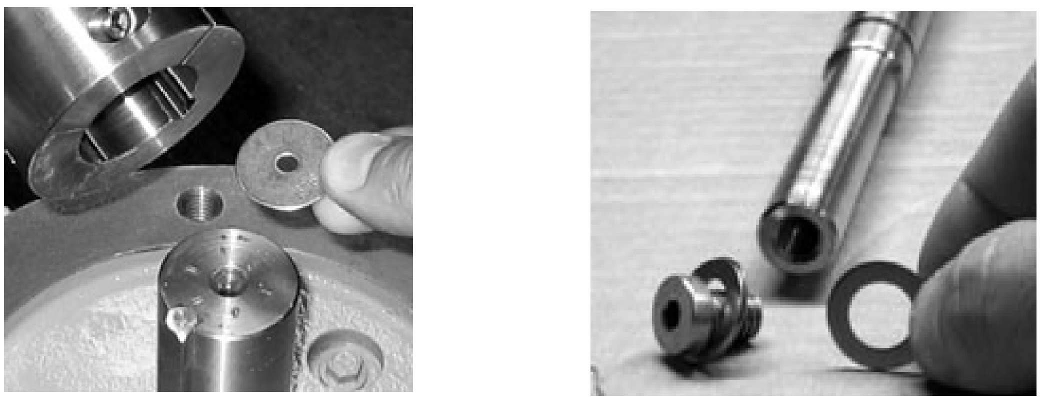
Figure 7-19 – Install Pump onto Bell Housing



11. Inspect the mechanical seal inside the inlet housing. Check the compression of the mechanical seal by looking into the circular window as shown in Figure 7-20. If seal is not correctly compressed, remove the pump and install a fender washer into the shaft coupling or a shim spacer onto the shaft as shown in Figure 7-21. Reassemble pump according to the steps above.

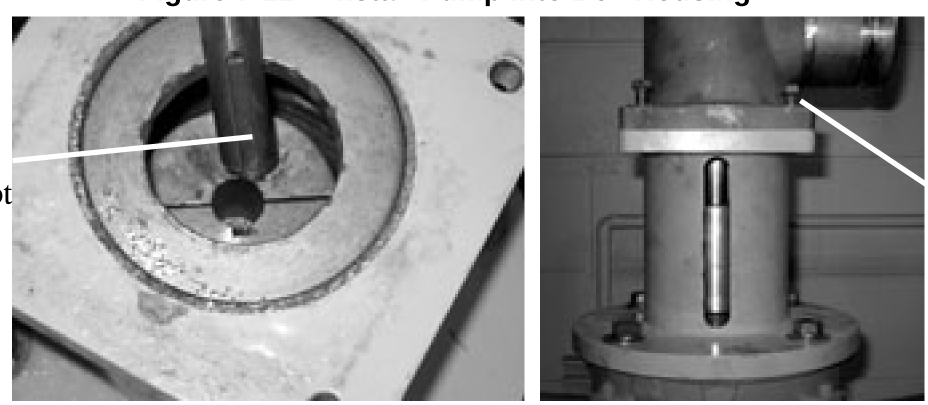
Figure 7-20 - Check Seal Compression

Figure 7-21 – Add or Remove Fender Washer(s) or Shim Spacer(s) to Change Seal Compression



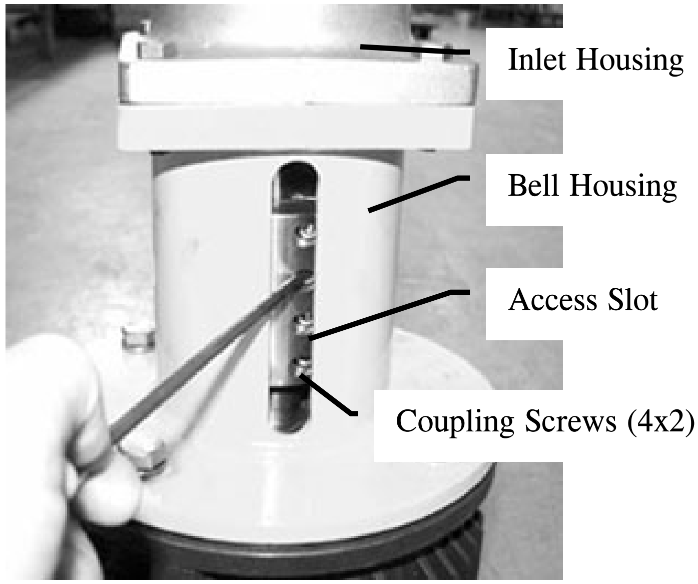
12. Verify that the shaft keys are in place.
13. Line up the key of the pump shaft with the slot in the shaft coupling inside the bell housing as shown in Figure 7-22 below.
14. Install the pump head onto the bell housing. Install the four (4) bolts between the pump to finger tight.

Figure 7-22 – Install Pump into Bell Housing



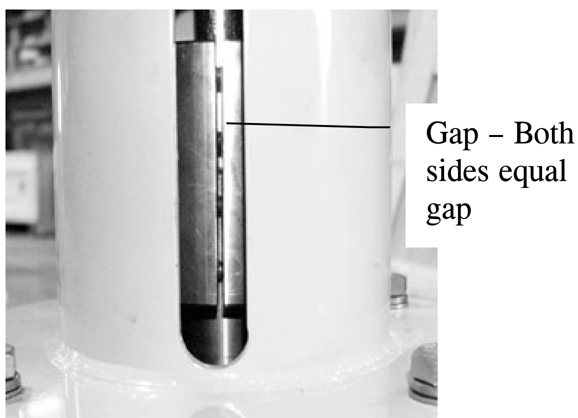
15. With the pump and motor shafts in contact, tighten the eight (8) coupling screw as shown in Figure 7-23. NOTE: THE PUMP AND MOTOR SHAFT MUST BE IN CONTACT.

Figure 7-23 – Tighten Coupling onto Shafts



16. Tighten both halves of the coupling evenly making sure that the gap between the two halves is equal as shown in Figure 7-24.

Figure 7-24 - Check Gap Between Coupling Halves



17. Torque the coupling screws according to the requirements listed in Table 7-4. Make sure the gap between the two halves of the coupling is even on both sides as shown in Figure 7-24. The coupling must be tightened evenly and fully to prevent an out of balance condition, excessive vibration and premature motor bearing failure.

Table 7-4 - Shaft Coupling Torque Requirements

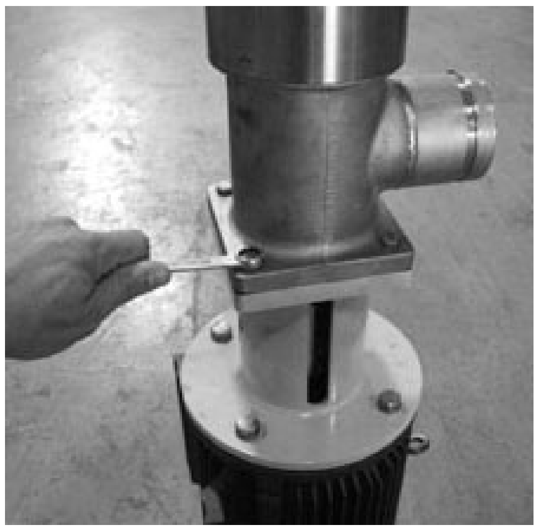
	HP-8503	HP-8504	HP-1253	HP-1254	HP-2402	HP-2403
Coupling Screw Torque	8 ft-lb / 11 N-m	8 ft-lb / 11 N-m	8 ft-lb / 11 N-m	8 ft-lb / 11 N-m	12 ft-lb / 16 N-m	12 ft-lb / 16 N-m

CAUTION

The coupling screws must be tightened evenly according to the torque requirements. The gap between the two halves of the coupling must be equal on both sides. Failure to tighten the coupling evenly and fully could cause an out of balance condition resulting in excessive vibration and premature motor bearing failure.

18. Tighten the four (4) bolts between the inlet housing and the bell housing. Torque bolts to 12 ft-lbs (16 N-m) as shown in Figure 7-25. If the bolts between the pump and the bell housing were tightened before the shaft coupling was tightened, loosen all four (4) bolts 2 revolutions. Then torque the four (4) bolts between the inlet housing and the bell housing to 12 ft-lbs (16 N-m) as shown in Figure 7-25.

Figure 7-25 – Final Step: Tighten Inlet to Bell Housing



CAUTION

Tighten coupling before tightening the bolts between the inlet housing and the bell housing.

19. Check to see that the shaft can turn relatively free by hand. The purpose for the ideal impeller gap spacing is to keep the impellers free inside the bowls. The bowls are held in place by the compression applied by the outlet nozzle while the splined shaft spins the impellers. If the gap spacing is incorrect and the impellers rub/ interfere with the bowls, premature failure of the pump may occur. A small amount of rubbing during an initial break in period is acceptable.
20. After the pump is reassembled and reinstalled, make sure that water is fully flowing through the unit before starting. THE PUMP CANNOT BE RUN DRY FOR EVEN A FEW SECONDS. Damage will occur in seconds if the pump runs with insufficient feed flow.

7.4 Disassembly of Wet End

The following procedure should be used when rebuilding the wet end of PX Booster Pumps.

1. Verify that the system is de-energized and un-pressurized.

2. Disconnect the inlet and outlet connections of the PX Booster Pump and allow water to drain from system.
3. Loosen the pump head with a pipe wrench on the outlet nozzle as shown in Figure 7-26.
4. Loosen the shell with a strap wrench as shown in Figure 7-27.

Figure 7-26 – Loosen Outlet Nozzle

Figure 7-27 – Loosen Shell

5. Stand up the PX Booster Pump in a vertical orientation as shown in Figure 7-1.
6. Remove the outlet nozzle and shell. Remove the snap ring from the end of the shaft.
7. Remove the stage assemblies down to the inlet nozzle as shown in Figure 7-28. Inspect all stage assemblies and components for damage and/or wear.

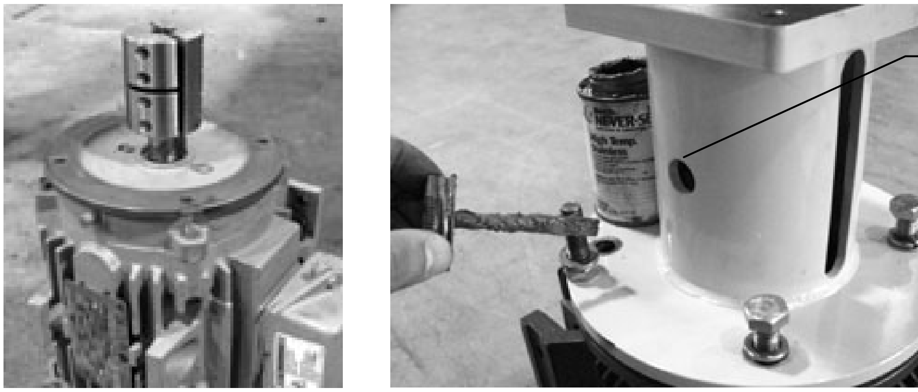
Figure 7-28 – Remove Shell and Stages

7.5 Assembly of Wet End

This procedure assumes that the pump has been completely disassembled.

1. Clean the face of the motor.
2. Clean the coupling components as shown in Figure 7-14 above. Install the shaft coupling onto the motor shaft as shown in Figure 7-29 below.
3. Install the bell housing as shown in Figure 7-29. Be sure the drainage hole is oriented downward toward the floor. Torque bolts to 40 ft-lbs (58 N-m).

Figure 7-29 - Install Coupling and Bell Housing

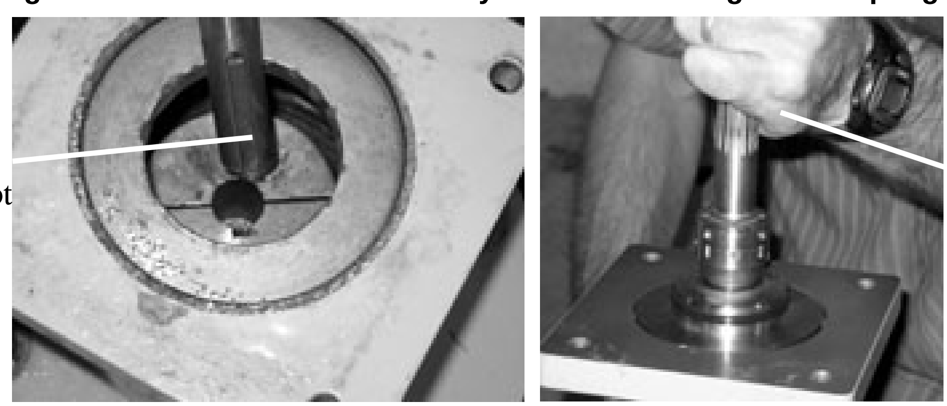


4. Install the seal and seal plate onto the shaft as shown in Figure 7-30.

Figure 7-30 – Install seal and seal plate onto shaft

5. Insert the shaft assembly into the bell housing as shown in Figure 7-31.
6. Check the seal compression while applying downward force on the pump shaft so that the pump shaft and motor shaft are in contact.

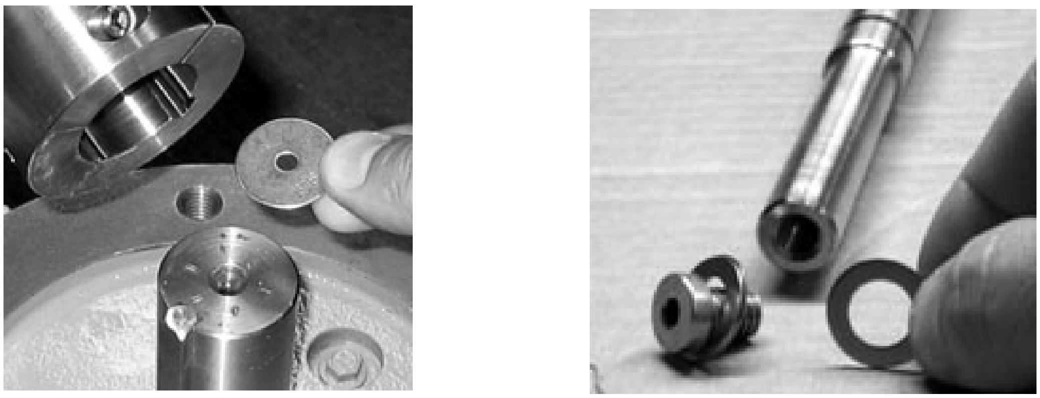
Figure 7-31 – Insert Shaft Assembly into Bell Housing and Coupling



7. Check the compression of the mechanical seal while applying downward force on the shaft by looking into the circular window as shown in Figure 7-32. If seal is not correctly compressed, remove the pump and install a fender washer into the shaft coupling or a shim spacer onto the shaft as shown in Figure 7-33. Reassemble pump according to the steps above.

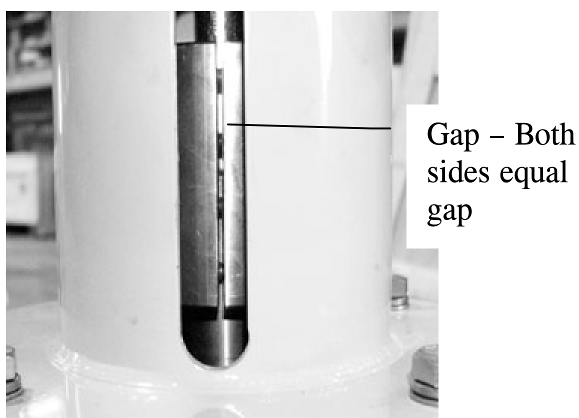
Figure 7-32 - Check Seal Compression

Figure 7-33 – Add or Remove Fender Washer(s) or Shim Spacer(s) to Change Seal Compression



8. When the seal compression is correct, torque the coupling screws according to the requirements listed in Table 7-4 above. Make sure the gap between the two halves of the coupling is even on both sides as shown in Figure 7-34. The coupling must be tightened evenly and fully to prevent an out of balance condition, excessive vibration and premature motor bearing failure.

Figure 7-34 - Check Gap Between Coupling Halves



9. Install the first impeller. Set the gap between the impeller and the wear ring of the diffuser plate to 1/16" (1.6mm) $\pm$ 1/32” (0.8mm) as shown in Figure 7-35. Remove the impeller and add or subtract spacers onto the shaft as necessary to adjust the gap. For 2400-Series PX Booster Pump models, the gap between the impeller and the wear ring cannot be directly viewed. In this case, measure the distance between any two features on the diffuser plate and the impeller as shown in Figure 7-36. Record the measurement. Then raise the

diffuser plate until it contacts the impeller. Measure the gap again. The difference between the measurements indicates the gap distance. Remove the impeller and add or subtract spacers onto the shaft as necessary to adjust the gap.

Figure 7-35 - Install First Diffuser Plate

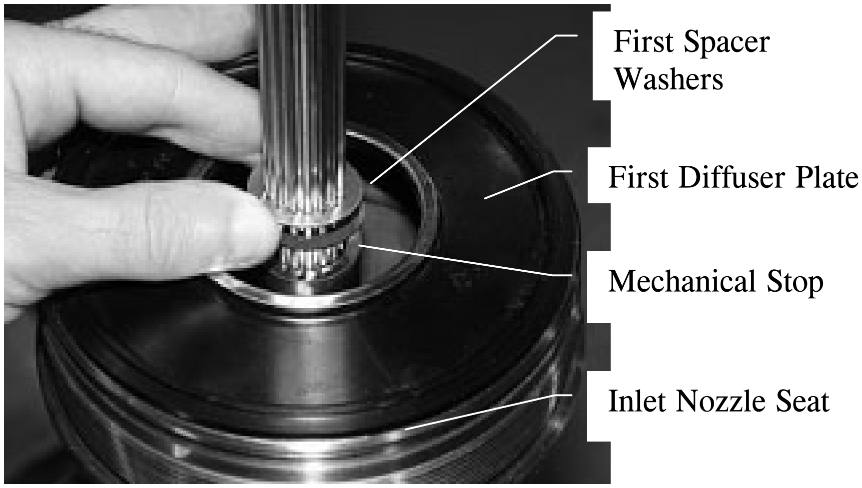


Figure 7-36 - Adjust the Gap Between the Impeller and Diffuser Plate Using Spacers

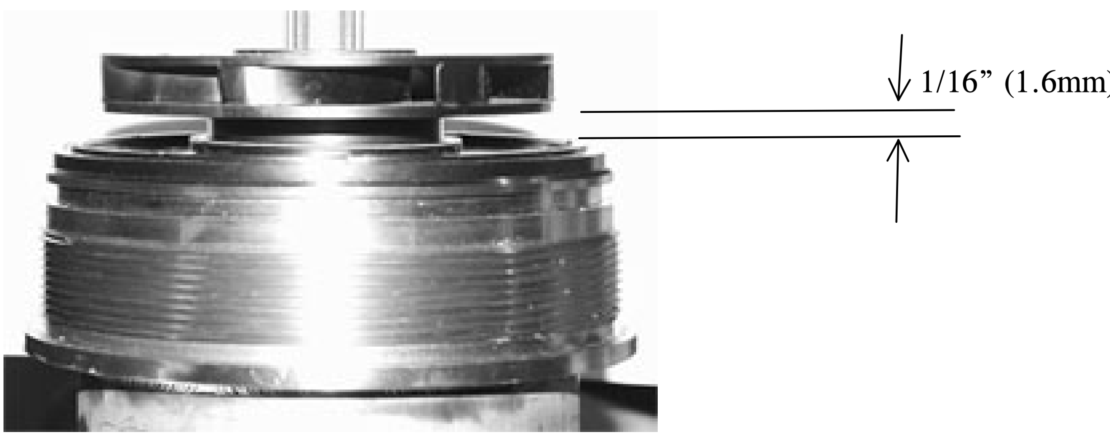
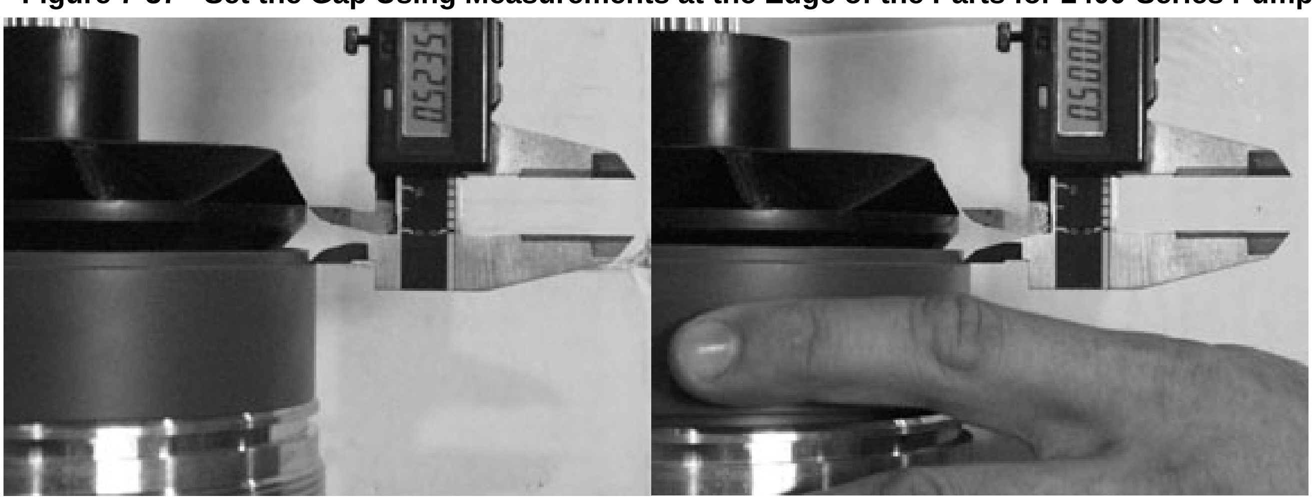


Figure 7-37 - Set the Gap Using Measurements at the Edge of the Parts for 2400-Series Pumps



10. The next item to go on the shaft is a thrust washer, then a bearing journal, then a diffuser bowl. The diffuser bowl, spacer washer (optional), bearing journal, thrust washer, impeller and diffuser plate make up a complete stage assembly as shown in Figure 7-38. Stack in the order shown in Figure 7-38 or 7-39 until the pump is complete.

Figure 7-38 - Complete Stage Assembly for 8500- and 1250-Series Pumps

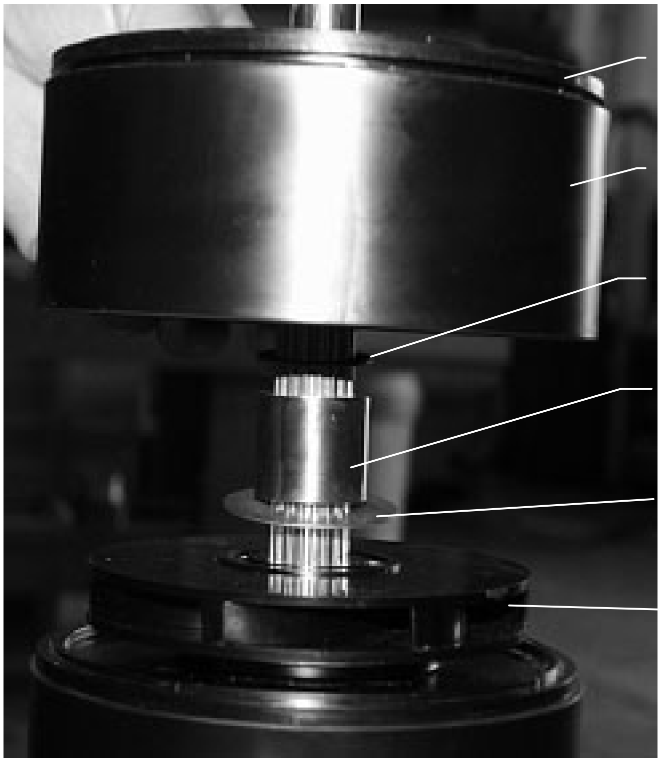


Figure 7-39 - Complete Stage Assembly for 2400-Series Pumps

11. Install the last diffuser plate. Install the snap ring as shown in Figure 7-40 or 7-41.

Figure 7-40 - Install Snap Ring, 2400-Series

Figure 7-41 - Install Snap Ring, 8500-, 1250-Series

12. Install the shell. Apply anti-seize only to the threads of the inlet housing and shell and wipe away excess. Use a lot of anti-seize to avoid galling and to facilitate disassembly, however, avoid getting anti-seize on the o-ring. Lubricate the o-ring with glycerin or liquid soap and install.
13. Screw the shell on to the inlet until it bottoms out and then apply enough torque with a strap wrench to make it tight as shown in Figure 7-43 below.
14. Install the outlet nozzle. Use sufficient anti-seize to avoid galling and to facilitate disassembly. Apply anti-seize only to the threads, wipe away excess and avoid getting anti-seize on the o-ring. Lubricate o-ring and install outlet nozzle. Apply 150 ft-lb (+20 ft-lbs – 0 ft-lbs) of torque to the outlet nozzle with a pipe wrench as shown in Figure 7-44 below. Insufficient torque will result in the bowls breaking free, spinning and pump failure.

Figure 7-42 - Install Shell and Outlet Nozzle

Figure 7-43 – Tighten Shell

Figure 7-44 – Tighten Outlet Nozzle

CAUTION — Insufficient torque on the outlet nozzle will result in the bowls spinning and pump failure.

15. At this point the wet end is completely reassembled. Check to see that the shaft can turn relatively free by hand. The purpose for the ideal impeller gap spacing is to keep the impellers free inside the bowls. The bowls are held in place by the compression applied by the outlet nozzle while the splined shaft spins the impellers. If the gap spacing is incorrect and the impellers rub/ interfere with the bowls, premature failure of the pump may occur. A small amount of rubbing during an initial break in period is acceptable.

After the pump is reassembled and back on the RO plant make sure that water is fully flowing through the unit before starting. The pump cannot be run dry for even a few seconds. Damage will occur in seconds if the pump runs with insufficient feed flow. Refer to Section 6.2 for complete start up procedures.

CAUTION — Never run the PX Booster Pump dry or with low feed flow. Operating with feed pressures less than 15 psi (1 bar) or below recommended the flow range can cause damage to the pump's internal components.

7.6 Motor Bearing Service

The motor bearings in ERI motors will provide a long service life if properly and regularly lubricated. The motor manual included in Section 12.0 provides guidance for proper motor maintenance. In case of bearing failure, ERI supplies the replacement bearings listed in Table 7-5.

Table 7-5 – Replacement Motor Bearings

BOOSTER PUMP MODEL	BACK LOAD BEARING	FRONT THRUST BEARING
HP-8503	10228-01	10227-01
HP-8504	10228-02	10227-03
HP-1253 GE	10228-02	10227-03
HP-1253 Leeson	10228-05	10227-04
HP-1254	10228-04	10227-02
HP-2402	10228-04	10227-02
HP-2403	10228-04	10227-02

In addition to the replacement bearings, the following tools are required: bearing puller, bearing heater, snap ring removal tool, rubber mallet, all-thread, and appropriate sockets and/or wrenches.

The following procedure describes removal and replacement of motor bearings. Consult the current motor manual on the motor vendor's website for additional guidance or information:

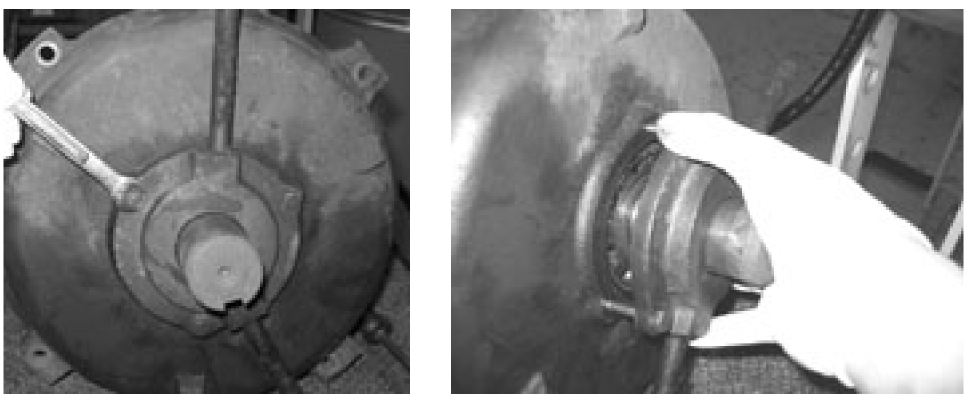
LEESON: http://www.leeson.com/literature/tech_info/
GE: http://www.geindustrial.com/cwc/library?famid=23&lang=en_US)

DANGER

Ensure motor is disconnected from power source before servicing.

1. Verify that the system is de-energized and de-pressurized. Disconnect the motor from the power source.
2. Disconnect the inlet and outlet connections of the PX Booster Pump and allow water to drain from system.
3. Disconnect and remove pump head according to steps 1 though 6 of the Mechanical Seal Change procedure provided in Section 7.3 .
4. Remove the bell housing.
5. Remove the coupling from the motor shaft. Disassemble the coupling as shown in Figure 7-10. Clean the coupling and the shaft keys to remove any salt deposits or debris.
6. Remove the fan cover from the motor.
7. Remove fan snap ring.
8. Remove the fan.
9. Remove the rubber slingers (x2).
10. Remove the bearing lubrication covers (x2). See Figure 7-45.

Figure 7-45 – Remove Bearing Lubrication Covers

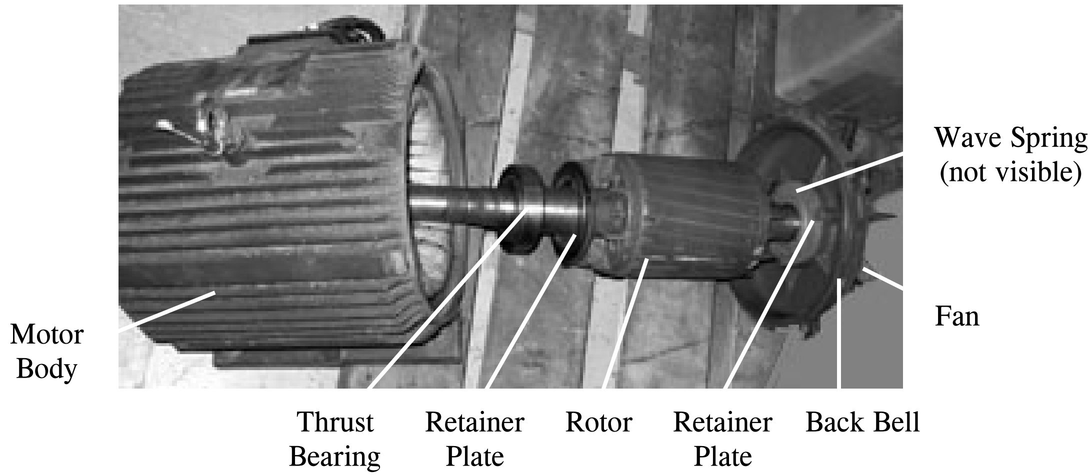


11. Remove the front bell from the motor body. See Figure 7-46.

Figure 7-46 – Remove Front Bell

12. Remove the back bell and the rotor and shaft assembly from the front of the motor body. See Figure 7-47.

Figure 7-47 – Remove Rotor and Shaft Assembly



13. Remove the thrust bearing retaining ring. See Figure 7-48.

Figure 7-48 – Remove Bearing Retaining Ring

14. Use a bearing puller to remove the thrust bearing from the front of the shaft and the back bearing from the back of the shaft. See Figure 7-49.

Figure 7-49 – Pull Bearing with Bearing Puller

15. To install replacement bearings, heat inner bearing ring to 180°F (82°C) and slide onto shaft. See Figure 7-50.

Figure 7-50 – Heat Inner Ring to 180°F (82°C)

16. Insert rotor assembly into motor body.
17. Install back bell onto rotor and shaft assembly. It maybe necessary to tap back bell with a rubber mallet to ease the assembly process.
18. Ensure wave spring is inside counterbore in back motor bell.
19. Slide bearing lubrication cover onto shaft.
20. Use a piece of all thread to pull back bearing retainer cover towards the bearing lubrication cover. Install bolts to fasten back bearing retainer cover to bearing lubrication cover as shown in Figure 7-51.

Figure 7-51 – Use All-thread to Align Retainer Plate

21. Bolt on back motor bell.
22. Reinstall back rubber slinger.
23. Install fan.
24. Install fan retaining ring.
25. Install fan cover.
26. Repeat the preceding steps for front motor bell installation.
27. Grease the bearings with a grease gun through the grease fittings. Use a high-quality bearing grease such as Shell Dolium R or Chevron SR1 2.
28. Reassemble the pump according the procedures provided above.

29. After motor is assembled and connected to power supply, apply power momentarily then switch off (bump). Retighten the bolts on the front and back motor bells.

8.0 TROUBLE SHOOTING

This section is designed to guide the operator in determining the probable cause of the most frequently encountered problems. This section can only be a guide to solving potential problems within the pressure exchanger system and cannot contain all possible malfunctions, nor can it contain all possible ways to determine the cause of a malfunction. The best troubleshooting tool is the knowledge of the plant gained through experience. Any condition 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. Checking for continuity and solid contact can prevent hours of wasted effort.
3. Always inspect and test equipment or apparatus for probable cause of malfunction before performing replacement.

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

Table 8-1 - Troubleshooting

SYMPTOM	PROBABLE CAUSE	CORRECTIVE ACTION
A. Motor fails to start upon initial installation	Motor is miswired.	Rewire motor according to wiring schematic provided.
	Motor damaged and rotor is striking stator.	May be able to reassemble; otherwise, motor should be replaced.
	Fan guard bent and contacting fan.	Replace fan guard.
B. Motor has been running, then fails to start.	Fuse or circuit breaker tripped.	Replace fuse or reset the breaker.
	Stator is shorted or went to ground. Motor will make a humming noise and the circuit breaker or fuse will trip.	Disassemble motor and inspect windings and internal connections. A blown stator will show a burn mark. Motor must be replaced or the stator rewound.
	Motor overloaded or load jammed.	Inspect to see that the load is free. Verify amp draw of motor versus nameplate rating.

	Capacitor (on single phase motor) may have failed.	First discharge capacitor. To check capacitor, set volt-ohm meter to RX100 scale and touch its probes to capacitor terminals. If capacitor is OK, needle will jump to zero ohms, and drift back to high. Steady zero ohms indicates a short circuit; steady high ohms indicates an open circuit.
	Starting switch has failed.	Disassemble motor and inspect both the centrifugal and stationary switches. The weights of the centrifugal switch should move in and out freely. Make sure that the switch is not loose on the shaft. Inspect contacts and connections on the stationary switch. Replace switch if the contacts are burned or pitted.
C. Motor runs but dies down.	Voltage drop.	If voltage is less than 10% of the motor's rating contact power company or check if some other equipment is taking power away from the motor.
	Load increased.	Verify the load has not changed. Verify equipment hasn't got tighter. If fan application verify the air flow hasn't changed.
D. Motor takes too long to accelerate.	Defective capacitor	Test capacitor per previous instructions.
	Faulty stationary switch.	Inspect switch contacts and connections. Verify that switch reeds have some spring in them.
	Bad bearings.	Noisy or rough feeling bearings should be replaced.

	Voltage too low. Make sure that the voltage is within 10% of the motor's name.	plate rating. If not, contact power company or check if some other equipment is taking power away from the motor.
E. Motor overload protector continually trips.	Load too high.	Verify that the load is not jammed. If motor is a replacement, verify that the rating is the same as the old motor. If previous motor was a special design, a stock motor may not be able to duplicate the performance. Remove the load from the motor and inspect the amp draw of the motor unloaded. It should be less than the full load rating stamped on the nameplate.
	Ambient temperature too high.	Verify that the motor is getting enough air for proper cooling. Most motors are designed to run in an ambient temperature of less than 40°C. (Note: A properly operating motor may be hot to the touch.)
	Protector may be defective.	Replace the motor's protector with a new one of the same rating.
	Winding shorted or grounded.	Inspect stator for defects, or loose or cut wires that may cause it to go to ground.
F. Low flow and/or pressure.	Blockage in piping	Check valves and piping.
	Backwards motor rotation	Check rotation and electrical phase connections.
	Flow meter and/or gauge failure. Damaged or blocked stage assemblies.	Check and calibrate instruments and gauges. Check and replace stage assemblies as required.
G. Motor stalled	Power failure or trip.	Verify proper power and voltage connections. Check motor overload mechanisms. I.e. Fuses and /or circuit breakers.

	Jam or block in impeller and stage assemblies. Damaged motor.	Check fuses. Check and replace stage assemblies as required. Replace motor.
H. Leak	Leaky connection.	Check couplings.
	Mechanical seal failure. Damaged o-ring.	Inspect and/or replace mechanical seal. Inspect o-rings.
I. Excessive noise	Excessive flow rate. Insufficient feed water. Motor bearing failure.	Lower flow rate or apply backpressure to pump. Check feed pressure and inspect wet end assembly. Check motor bearings and/or replace motor.

ENERGY RECOVERY, INC. SAMPLE OPERATING LOG

NOTE: Daily data must be collected and maintained to support any warranty claims. Initial data must be submitted within 24 hours of startup.

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

Model of PX Booster Pump ____

Serial Number(s) ____

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

Date	Total Hours	HP Inlet Pressure	HP Outlet Pressure	HP Flow	Motor Bearings Lubricated?

9.0 ERI FIELD COMMISSIONING

The Technical Services staff of ERI offers commissioning service for all our related products whether it is in a field installation or at a RO 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, our Technical Services group is prepared to handle customers' concerns whether the location is domestic or overseas. Service rates are available upon request.

Energy Recovery, Inc.
1908 Doolittle Drive
San Leandro, CA 94577 USA
Tel: +1 510 483 7370   Fax: +1 510 483 7371
Email: sales@energy-recovery.com   Web: www.energy-recovery.com

10.0 WARRANTY AND LIABILITY

Energy Recovery, Inc. (ERI) warrants that its PX Booster Pump(s) will not fail or malfunction as a result of defects in materials, workmanship, or design for a period of twelve (12) months from date of shipment.

Application

This Warranty (i) extends to the original purchaser only, (ii) covers a PX Booster Pump that is installed and put to use at the intended site and under the intended conditions (unless written approval for installation at some other location is obtained from ERI), and (iii) 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 Booster Pump 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 Booster Pump 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 Booster Pump 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 Booster Pump. These records must show that the PX Booster Pump is operated consistently within the maximum flow and pressure 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 Booster Pump and plant operating records at any time during normal working hours.

2. The maximum operating flow through the PX Booster Pump must not be less than the minimum rated capacity.

3. Maximum operating pressure must not exceed 1,200 psi [83 bar].

4. All piping shall be cleaned and flushed with water so that all construction debris is removed from the system before installing or operating the PX Booster Pump.

5. In preparation for extended plant shutdowns, PX Booster Pumps must be flushed with permeate and a biocide.

11.0 REVISION LOG

Table 11-1 - Revision Log

Revision	Description	Date	Approval
-	Initial Release	10-25-01	JPM
A	Update photos and as builts.	05-03-02	JPM
B	Update procedures and photos. Add seal compression and shim instructions.	11-21-03	RLS
1	Update spare parts numbers, seal change procedure, add RMA form, update drawings	5-13-04	RLS
2	Trademarks, revised pump curves, added motor bearing service, added warranty	1-24-05	RLS
3	Revised warranty, pump curves	8/11/05	RLS

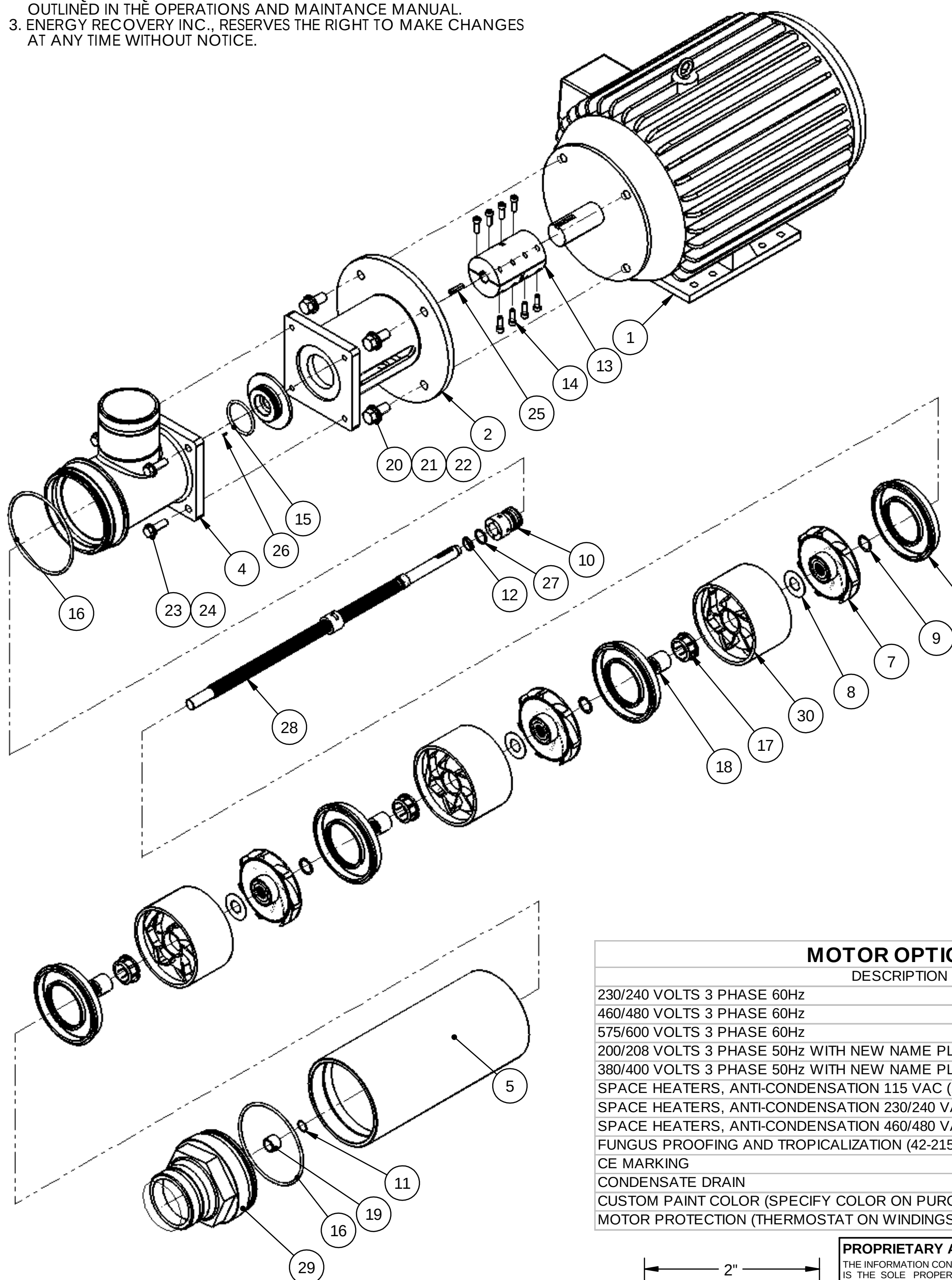
12.0 DRAWINGS AND DATA

1. PX Booster Pump Assembly Drawings, Overall Dimensions and Labeling Diagrams, Shipping Configuration Drawings
2. PX Booster Pump Characteristic (Pump) Curves

NOTES:
1. COAT STEPPED COUPLING BORES AND ALL THREADED FASTENERS WITH ANTI-SIEZE COMPOUND AT ASSEMBLY.
2. USE REQUIRED QTY OF SPACER WASHERS TO ACHIEVE SPACING OUTLINED IN THE OPERATIONS AND MAINTANCE MANUAL.
3. ENERGY RECOVERY INC., RESERVES THE RIGHT TO MAKE CHANGES AT ANY TIME WITHOUT NOTICE.

BILL OF MATERIALS

ITEM NO.	-01/QTY.	PART NO.	DESCRIPTION	MATERIAL
1	1	51036-01	MOTOR 10 H.P., 215T, BOLT ON C-FLANGE	---
2	1	51000-01	HOUSING, BELL, BOOSTER PUMP	ALUM
3	1	51008-01	PLATE, SEAL	AL6XN
4	1	51005-01	INLET, BOOSTER PUMP	AL6XN
5	1	51011-03	SHELL, BOOSTER PUMP	AL6XN
6	4	10143-01	PLATE, DIFFUSER, 120 SERIES	NORYL/AL6XN
7	3	10147-01	IMPELLER, PLATE, SERIES 120	NORYL
8	3	51026-01	WASHER, THRUST	AL6XN
9	6	51027-01	WASHER, SPACER	AL6XN
10	1	10123-01	SEAL, SHAFT, MECHANICAL	316SS
11	1	10061-01	RING, RETAINING	C-276
12	1	10066-01	RING, RETAINING	C-276
13	1	51029-01	COUPLING, STEPPED, 1 3/8" X 5/8"	TITANIUM
14	8	10054-01	SHCS, 1/4-28 X 3/4" LG, CLASS 3A	316 SS
15	1	10160-01	O-RING, -225	EPDM
16	2	10163-01	O-RING, -249	EPDM
17	3	10141-01	BUSHING, RUBBER	RUBBER
18	3	51025-01	JOURNAL, BEARING	AL6XN
19	1	51003-01	BUSHING, SLEEVE, .625 ID	RULON
20	4	10068-01	WASHER, FLAT, 1/2", TYPE A	18-8 SS
21	4	10044-01	WASHER, SPLIT LOCK	316 SS
22	4	10067-01	HHB, 1/2-13 X 1 1/4" LG	316 SS
23	4	10038-01	WASHER, FLAT, 3/8"	316 SS
24	4	10070-01	HHB, 3/8-16 X 1 1/4" LG	316 SS
25	1	51041-01	3/16" SQ X 1" LG KEY	316 SS
26	1	10117-01	DOWEL, 3/32" DIA X 1/4" LG	ACETAL
27	1	10122-01	SPACER, SEAL	PVC
28	1	51051-01	ASSY, SHAFT, ALL-SPLINE, 1253 PUMP	AL6XN
29	1	51002	NOZZLE, OUTLET, BOOSTER PUMP	AL6XN
30	3	10139-01	BOWL, DIFFUSER, 120 SERIES	NORYL



MECHANICAL SEAL KIT, ERI P/N 20004-01
HP-1253, 3-STAGE REBUILD KIT, ERI P/N 20007-01
HP-1253, O-RING KIT, ERI P/N 20007-02
BOOSTER PUMP TOOL KIT, ERI P/N 20003-01

MOTOR OPTIONS

DESCRIPTION
230/240 VOLTS 3 PHASE 60Hz
460/480 VOLTS 3 PHASE 60Hz
575/600 VOLTS 3 PHASE 60Hz
200/208 VOLTS 3 PHASE 50Hz WITH NEW NAME PLATE
380/400 VOLTS 3 PHASE 50Hz WITH NEW NAME PLATE
SPACE HEATERS, ANTI-CONDENSATION 115 VAC (182-215T NEMA FRAME SIZE)
SPACE HEATERS, ANTI-CONDENSATION 230/240 VAC (182-215T NEMA FRAME SIZE)
SPACE HEATERS, ANTI-CONDENSATION 460/480 VAC (182-215T NEMA FRAME SIZE)
FUNGUS PROOFING AND TROPICALIZATION (42-215T NEMA FRAME SIZE)
CE MARKING
CONDENSATE DRAIN
CUSTOM PAINT COLOR (SPECIFY COLOR ON PURCHASE ORDER)
MOTOR PROTECTION (THERMOSTAT ON WINDINGS)

2"
1"
REFERENCE SCALE

PROPRIETARY AND CONFIDENTIAL

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PRODUCT
DRAWING STATUS

INCH

UNLESS OTHERWISE SPECIFIED:
TOLERANCES:
FRACTIONAL: ± 1/32"
ANGULAR: MACH ±.5°
BEND ±1°
TWO PLACE DECIMAL: ±.01"
THREE PLACE DECIMAL: ±.005"
FOUR PLACE DECIMAL: ±.0002"
SURFACE FINISH:
ON PART 125 RMS
ON O-RING SURFACES 32 RMS
DIMENSIONING AND TOLERANCING PER ANSI Y14.5M (LATEST)
FINISH:
MATERIAL:
SHOWN

REV.	ECN NO.	DESCRIPTION	BY	DATE
1	04-064	CHANGE TO ALL SPLINE SHAFT	RAC	09/01/2004

REVISIONS

ENERGY RECOVERY INC.
1908 Doolittle Drive, San Leandro, CA 94577
Ph. (510)483-7370 / Fax: (510)483-7371
www.energy-recovery.com

DRAWN	RAC	05/12/2003
CHECKED	TLS	05/28/2003
ENG APPR.	RLS	05/28/2003

THIRD ANGLE PROJECTION

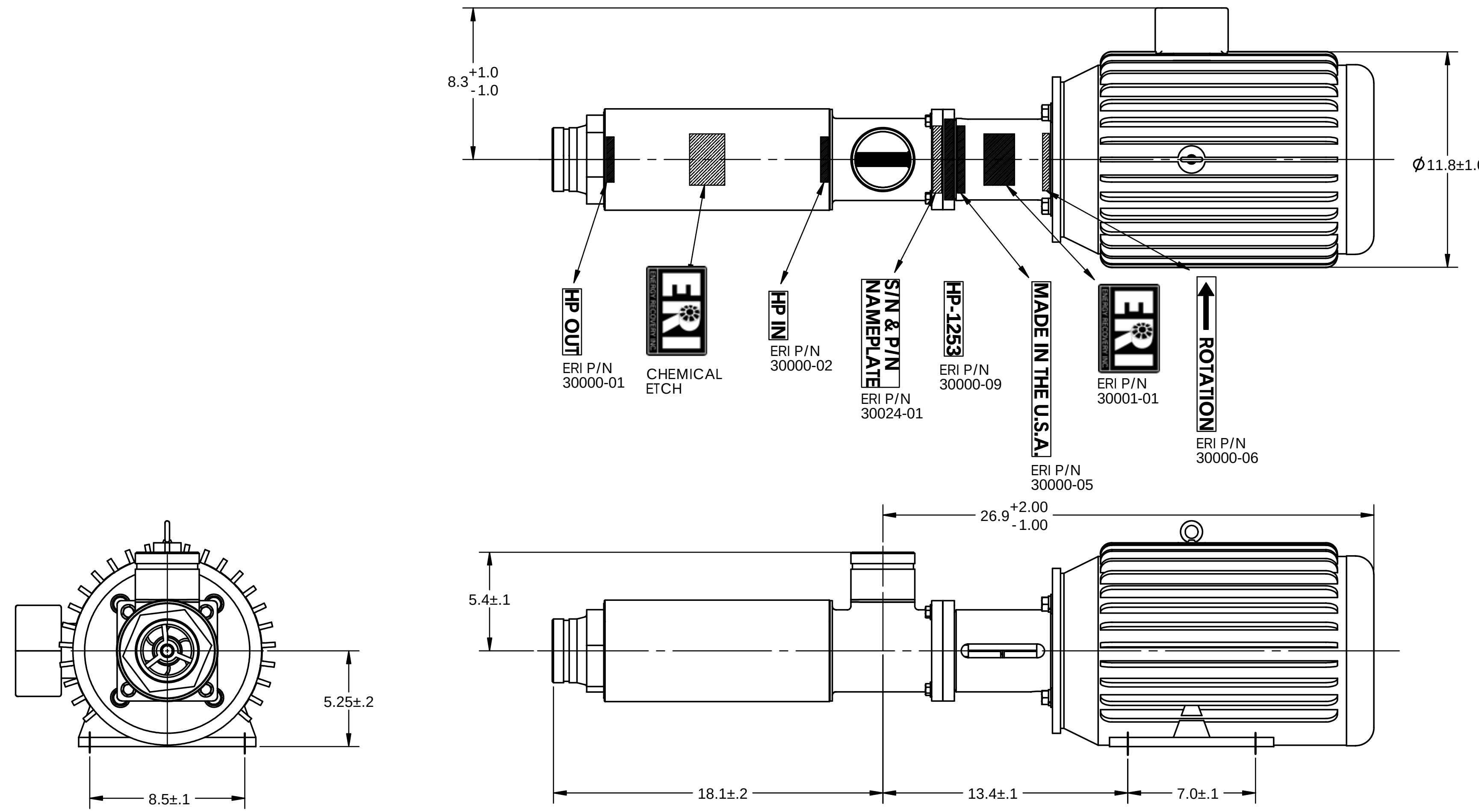
TITLE: ASSY, PUMP, BOOSTER, HP-1253

SIZE C | DWG. NO. 50002 | REV 1
SCALE: 1:1 | WEIGHT: | SHEET 1 OF 3

Wednesday, March 02, 2005 7:39:17 PM~C:\Engineering Documents\Production Drawings\50000 booster pump product assemblies\50002

NOTES:

1. MOTORS ARE CUSTOMIZED TO EMPLOY A SPECIAL THRUST BEARING. CONTACT ENERGY RECOVERY INC. FOR REPLACEMENT OR REPAIR.
2. MOTOR = 10 H.P. 215TC FRAME
3. ENERGY RECOVERY INC. RESERVES TO RIGHT TO MAKE SPECIFICATION OR DIMENSION CHANGES WITHOUT NOTICE.
4. LABEL LOCATIONS ARE APPROX AS SHOWN.



SEE SHEET 1 FOR REVISIONS

OVERALL DIMENSIONS LABEL LOCATIONS

SPECIFICATIONS:

MODEL: HP-1253
OPERATING FLOW RANGE: 40-190 GPM / 9-43 m3/hr
H.P. : 10
FULL LOAD 460VAC (AMPS): 12

REFERENCE SCALE: 2" / 1"

INCH

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CHECKED	TLS	05/28/2003
ENG APPR.	RLS	05/28/2003

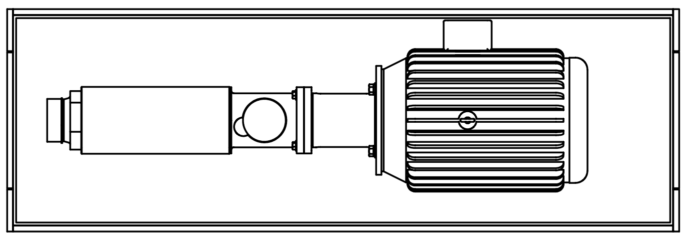
THIRD ANGLE PROJECTION

TITLE: ASSY, PUMP, BOOSTER, HP-1253

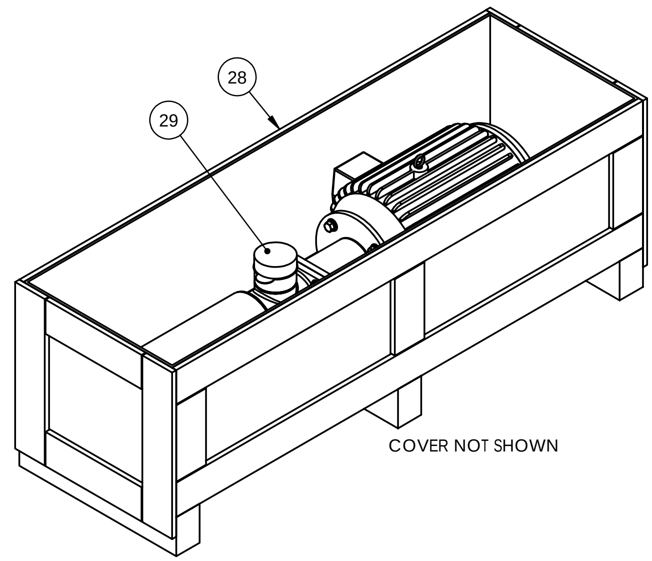
SIZE	DWG. NO.	REV
C	50002	1
SCALE: 1:4.5	WEIGHT:	SHEET 2 OF 3

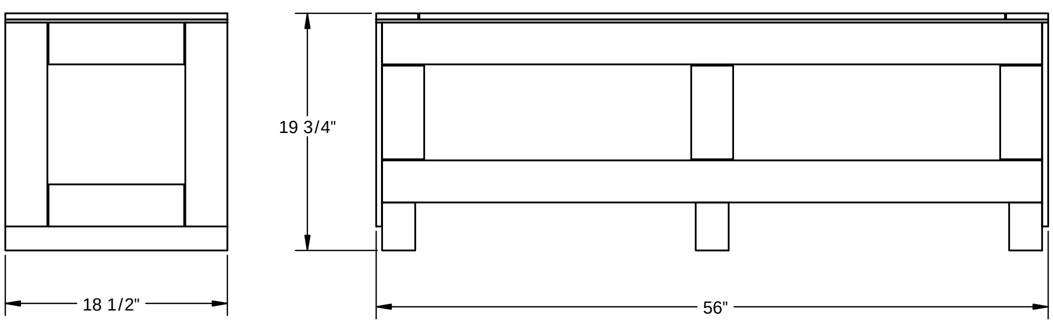
Wednesday, March 02, 2005 7:39:17 PM--C:\Engineering Documents\Production Drawings\50000 booster pump product assemblies\50002

BILL OF MATERIALS				
ITEM NO.	shipping/QTY.	PART NO.	DESCRIPTION	MATERIAL
28	1	10010-01	CRATE, SHIPPING, 54" X 16 1/2" X 14"	HT/KD WOOD
29	2	10011-01	CAP, PROTECTIVE	PLASTIC



COVER NOT SHOWN
ATTACH BOOSTER PUMP ASSEMBLY TO BOTTOM OF CRATE USING HEX BOLT/WASHER
SHORE PUMP TO KEEP FROM SHIFTING OR MOVEMENT INSIDE CRATE DURING TRANSIT





SEE SHEET 1 FOR REVISIONS

SHIPPING WEIGHT: 300 LBS / 136 Kgs

REFERENCE SCALE 1" 2"

INCH

ENERGY RECOVERY INC.
1908 Doolittle Drive, San Leandro, CA 94577
Ph. (510)483-7370 / Fax: (510)483-7371
www.energy-recovery.com

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PRODUCT
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DRAWN	RAC	05/12/2003
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ENG APPR.	RLS	05/28/2003

THIRD ANGLE PROJECTION

TITLE: ASSY, PUMP, BOOSTER, HP-1253

SIZE: C | DWG. NO.: 50002 | REV: 1

SCALE: 1:8 | WEIGHT: | SHEET 3 OF 3

Wednesday, March 02, 2005 7:39:17 PM~C:\Engineering Documents\Production Drawings\50000 booster pump product assemblies\50002

1908 Doolittle Dr.
San Leandro, CA
94577, USA
Phone: 510-483-7370
Fax: 510-483-7371

ENERGY RECOVERY, INC.
HP 1253
PX BOOSTER PUMP

SHEET
1 of 1

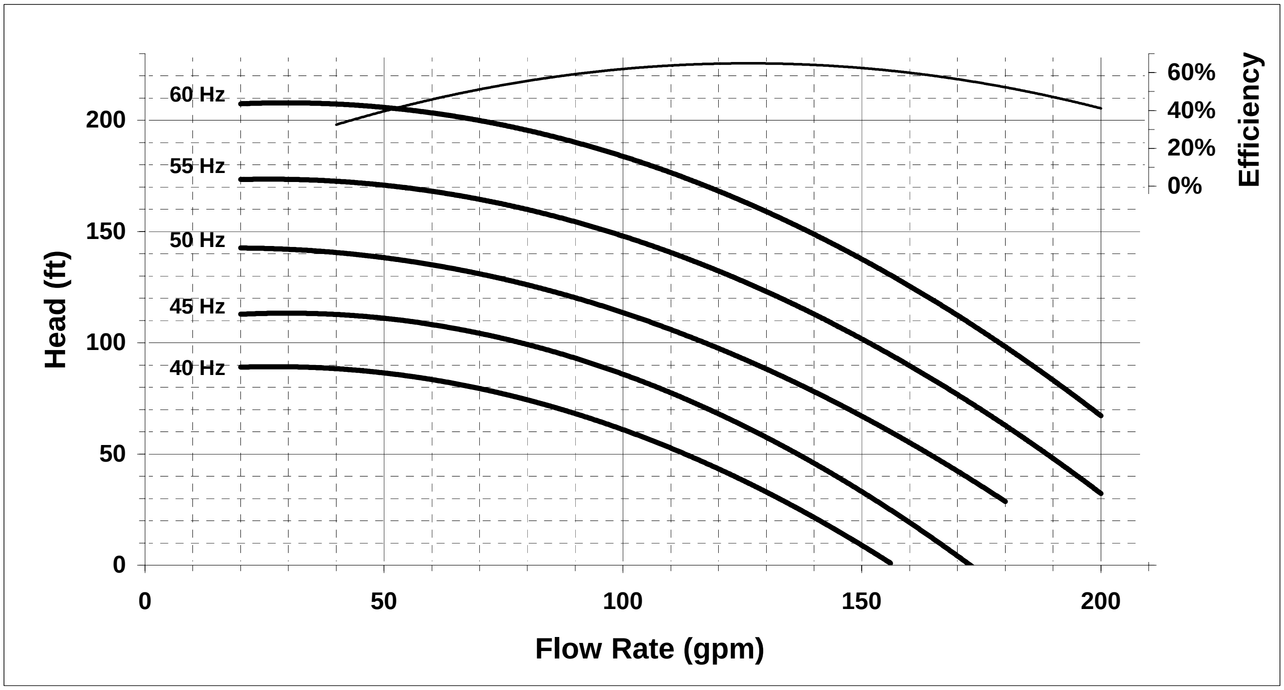
DOCUMENT NUMBER
80044-03

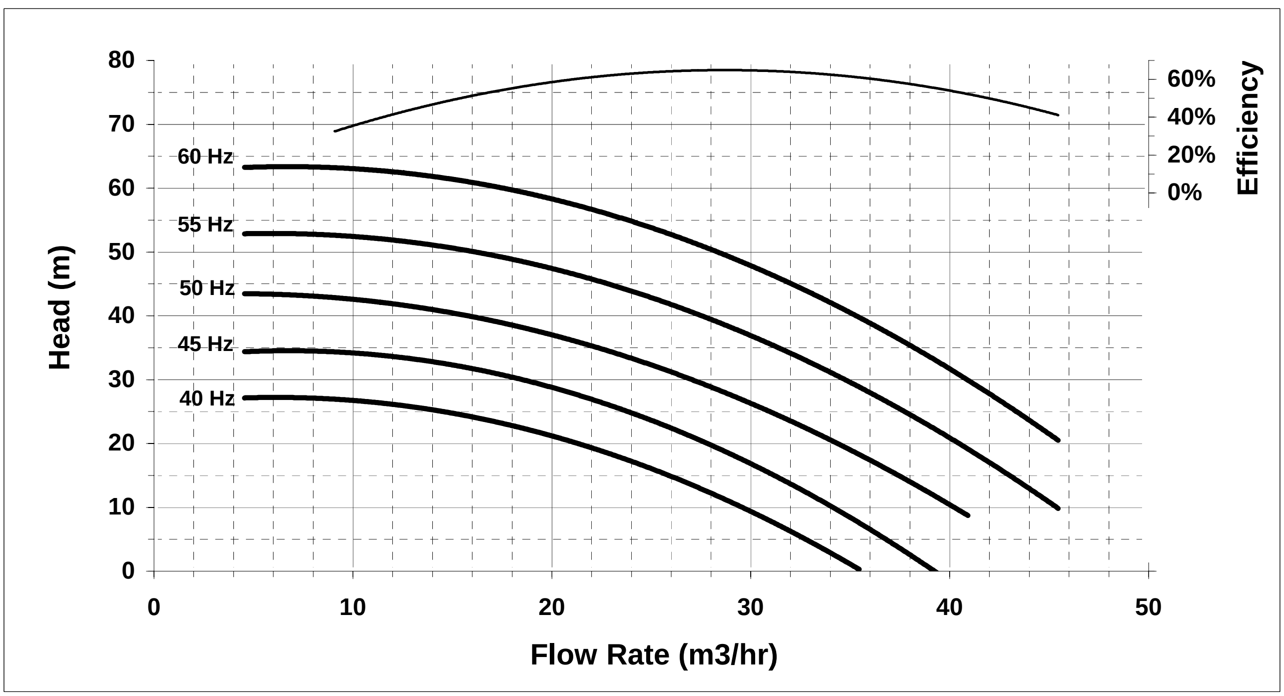
MANUFACTURER
ERI

DESCRIPTION

PUMP CURVES
HIGH-PRESSURE BOOSTER PUMP

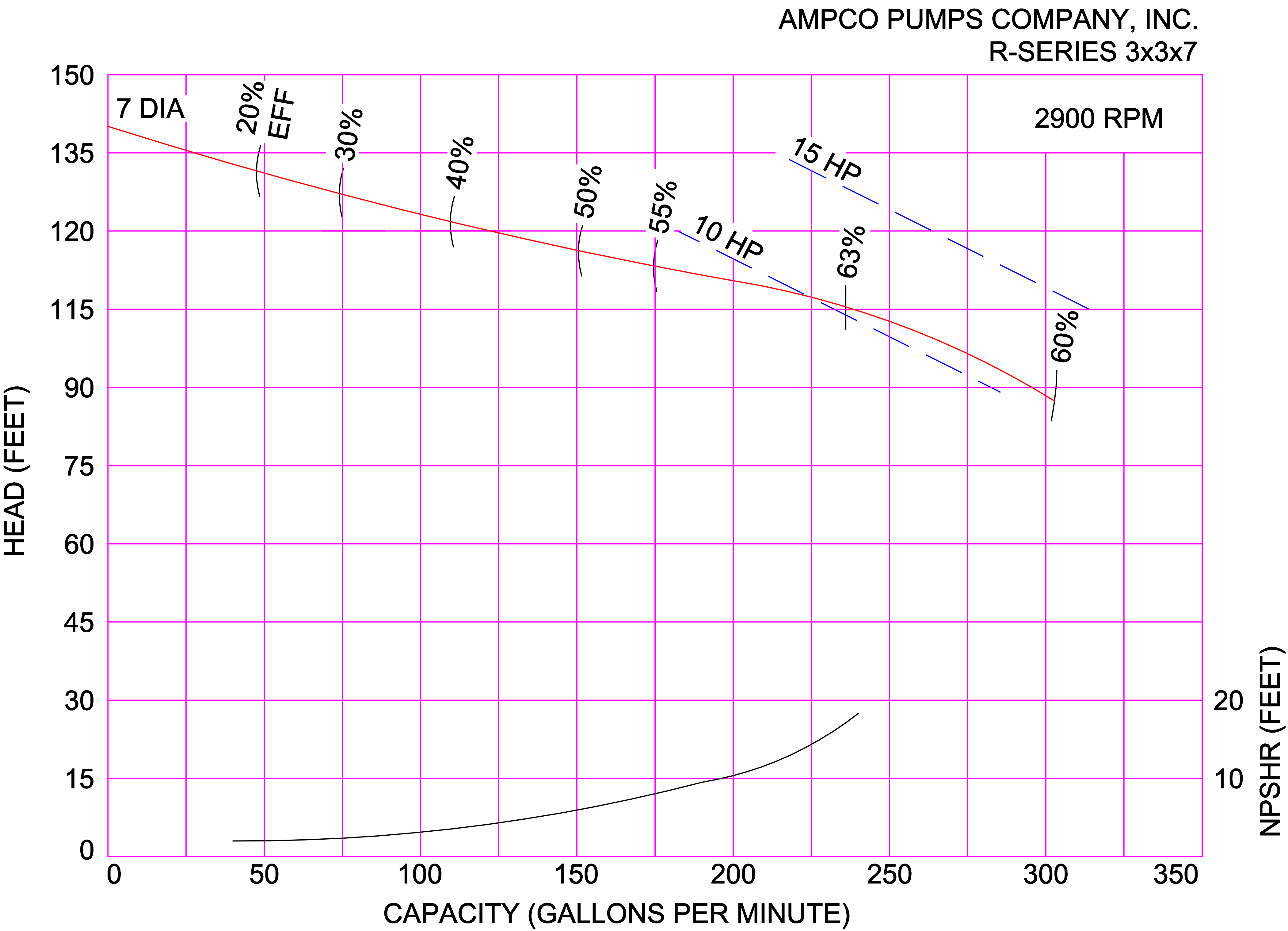
REV	BY	CKD	REVISION	DATE
000	RLS	JPM	Issued for Distribution	11/23/04
001	RLS	RBC	revised efficiency curve	7/12/05





Appendix E

Feed Pump

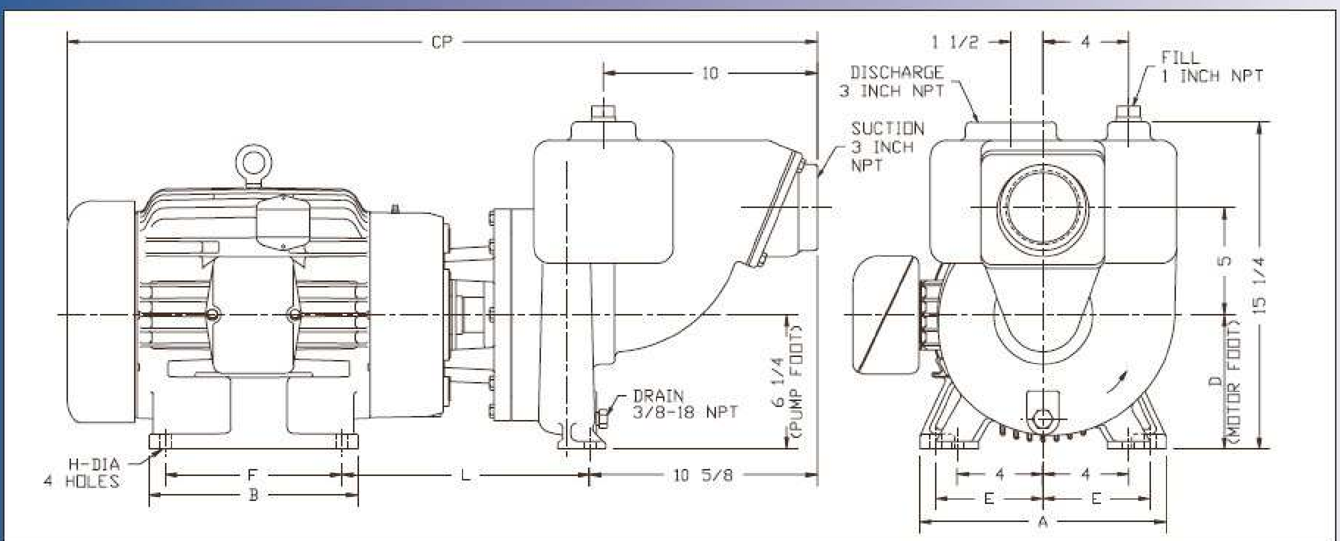


AMPCO PUMPS COMPANY, INC.
R-SERIES 3x3x7
7 DIA
20%
EFF
30%
40%
50%
55%
63%
60%
10 HP
15 HP
2900 RPM
HEAD (FEET)
NPSHR (FEET)
CAPACITY (GALLONS PER MINUTE)
0
15
30
45
60
75
90
115
120
135
150
10
20
50
100
150
200
250
300
350

Ampco Centrifugal Pumps

Data Sheet

Model RC2/RCH2 3X3x7



TEFC MOTOR			DIMENSIONS IN INCHES (For Reference Only)								APPROX. WEIGHT
HP	RPM	FRAME	A (max)	B (max)	D	E	F	H	L	CP	
2	1750	145JM	6-1/2	6	3-1/2	2-3/4	5	11/32	8-7/16	27-1/2	154
3	1750	182JM	8-5/8	6-1/2	4-1/2	3-3/4	4-1/2	13/32	9-1/16	28-3/4	180
5	1750	184JM	8-5/8	6-1/2	4-1/2	3-3/4	5-1/2	13/32	9-1/16	30-1/4	193
15	3500	254JM	11-1/2	9-3/4	6-1/4	5	8-1/4	17/32	11-9/16	35	376
20	3500	256JM	11-1/2	11-1/2	6-1/4	5	10	17/32	11-9/16	36-3/4	414
25	3500	284JM	12-3/4	12-3/4	7	5-1/2	9-1/2	17/32	11-9/16	40-9/16	544

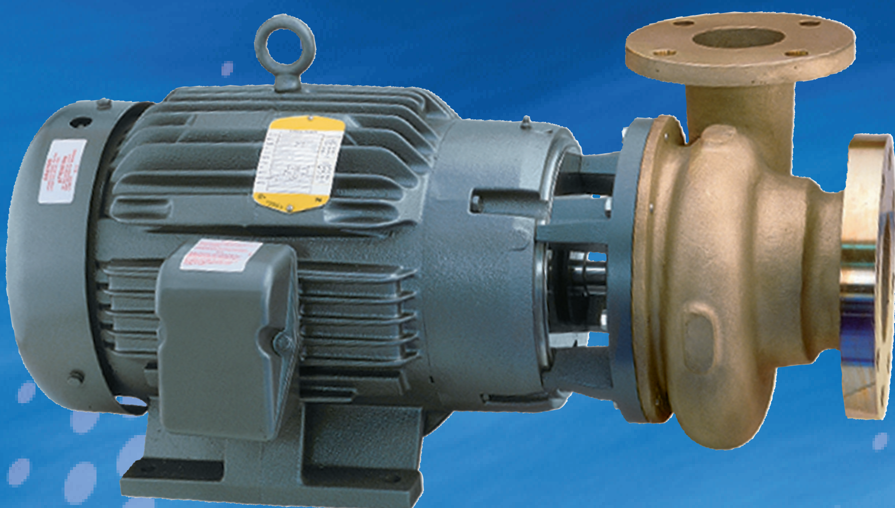
MATERIAL SPECIFICATIONS

PART NAME	NICKEL ALUMINUM BRONZE	STAINLESS STEEL
Casing, Impeller & Cover	AMPCO® 483	316 Stainless Steel
Shaft Sleeve	AMPCO® 18	316 Stainless Steel
Impeller Screw	AMPCO® 18	316 Stainless Steel
Motor Shaft	Steel	Steel
Adapter	Cast Iron	Cast Iron

Ampco Pumps Company

Marine and Industrial CENTRIFUGAL PUMPS

K SERIES
NICKEL ALUMINUM BRONZE
316 STAINLESS STEEL
DUPLEX 2205



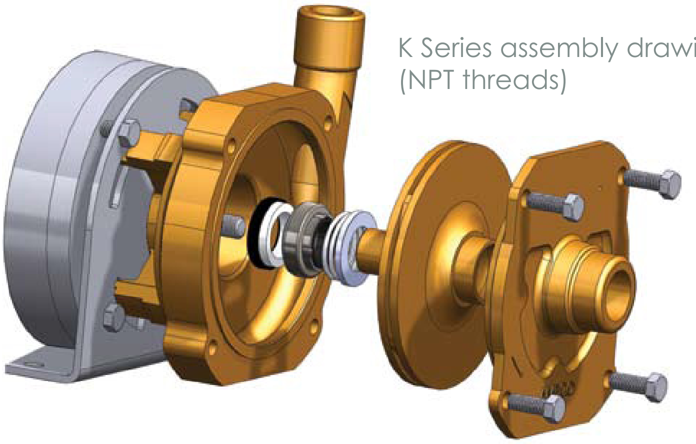
Z SERIES
NICKEL ALUMINUM BRONZE
316 STAINLESS STEEL
DUPLEX 2205

R SERIES
NICKEL ALUMINUM BRONZE
~~316 STAINLESS STEEL~~

Marine and Industrial Centrifugal Pumps

All K, Z, R Series pumps feature:

- Heavy-wall construction with tight manufacturing tolerances
- High-efficiency design with fully-shrouded, dynamically-balanced impellers
- Close-coupled on JM, 56J, IEC frame motors
- The standard seal is a T21 single mechanical with ceramic seat,carbon rotating element, Buna elastomers and 304SS metallics. Various other seal options are available.
- ABS (American Bureau of Shipping) type approval available
- Capacities from 5-3000 GPM, 1-680 m^3/h
- Bearing frame mounting available


K Series assembly drawing (NPT threads)

K Series

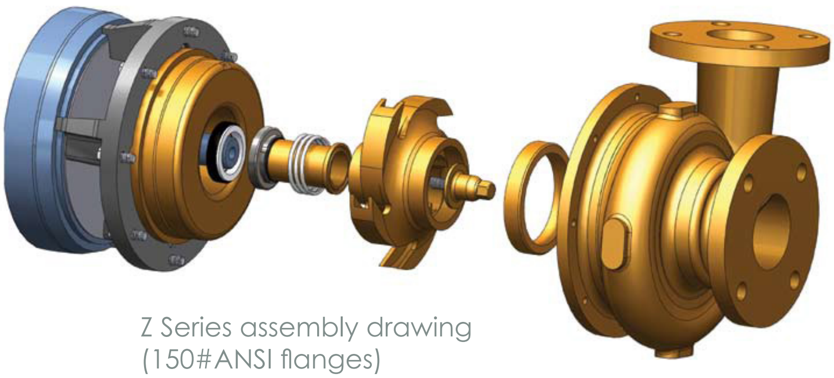
- Pressure up to 150 psi, 10 bar
- Temperatures up to 225°F, 105°C
- Multiple seal options
- Enclosed impellers
- Close-coupled to NEMA motor

R Series

- Self-priming up to 25 ft., 7.6m
- Pressure up to 175 psi, 12 bar
- Temperatures up to 225°F, 105°C
- Multiple seal options
- Enclosed impellers
- Close-coupled to NEMA or IEC motor

Z Series

- Pressure up to 175 psi, 12 bar
- Temperatures up to 250°F, 120°C
- Multiple seal options
- Internal Seal flush
- Replaceable wear rings
- Close-coupled to NEMA or IEC motor


Z Series assembly drawing (150#ANSI flanges)

Applications

- Commercial saltwater applications
- Reverse osmosis
- On-board vessels
- Engine cooling, condenser cooling, refrigeration and fire pumps
- Effluent waste water, brackish water

Available Alloys

Ampco offers pumps in nickel aluminum bronze, 316 stainless steel and Duplex 2205 stainless steel construction. All three alloys are in stock and available for delivery in one week. Ampco application engineers will help select the right alloy for the application.

Nickel aluminum bronze - Z, K, R

- Corrosion/erosion resistance to saltwater is far superior to stainless steel or standard bronzes
- Cost effective material for saltwater, brackish water and waste water
- The U.S. Navy has been using CDA958 in saltwater applications for over 40 years
- Ampco's K, Z and R series pumps have been used on most of the U.S. Army's reverse osmosis systems since the 1980's

An Ampco KC2 pump is used to boost pressure on Highland Engineering Inc.'s 1500 ROWPU system

316 stainless steel - Z, K, R

- High resistance to corrosion from many chemical solutions
- The material of choice in food and beverage processing applications

Duplex 2205 - Z, K

- Recommended for saltwater applications with higher salinity (over 35,000 ppm), higher temperatures, and high concentration of hydrogen sulfides (such as pumping from a deep seawater well)
- Superior resistance to effects of cavitation
- Strong resistance to wear from abrasive media such as diatomaceous earth or ethanol

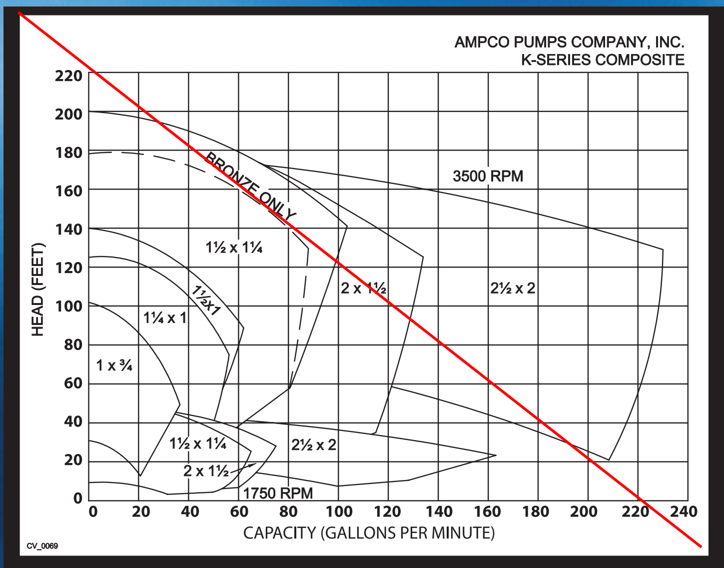
K, Z and R Series pumps are also available in specialty alloys such as Hastalloy C, Alloy 20, and 316L stainless steel.

A complete alloy compatibility chart is available at www.ampcopumps.com

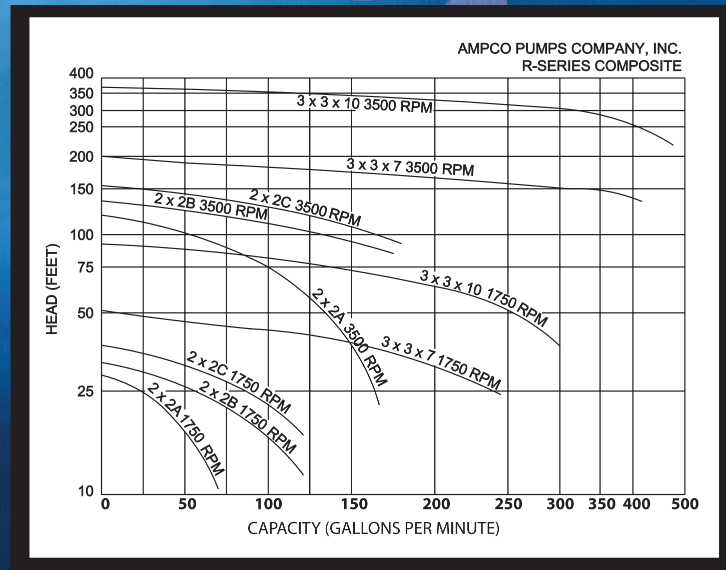
Reverse Osmosis and Desalinization

Ampco pumps are commonly used in difficult applications in wastewater and desalinization industries.

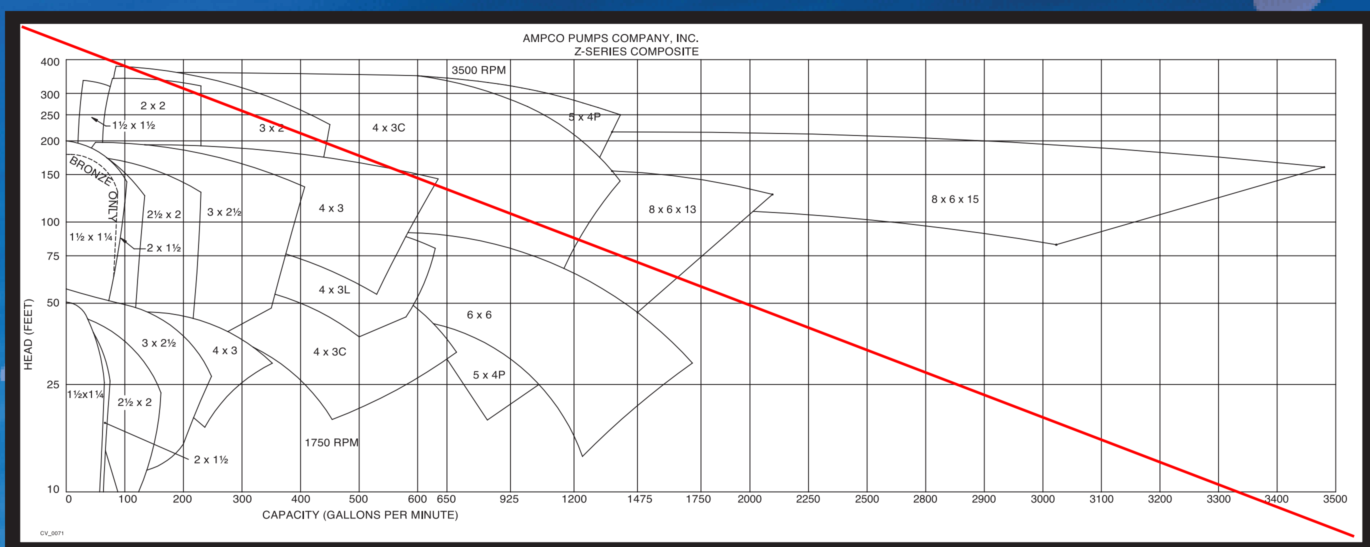
K Series



R Series



Z Series



All assembled Ampco pumps are tested to verify hydraulic, mechanical and electrical performance prior to shipment.

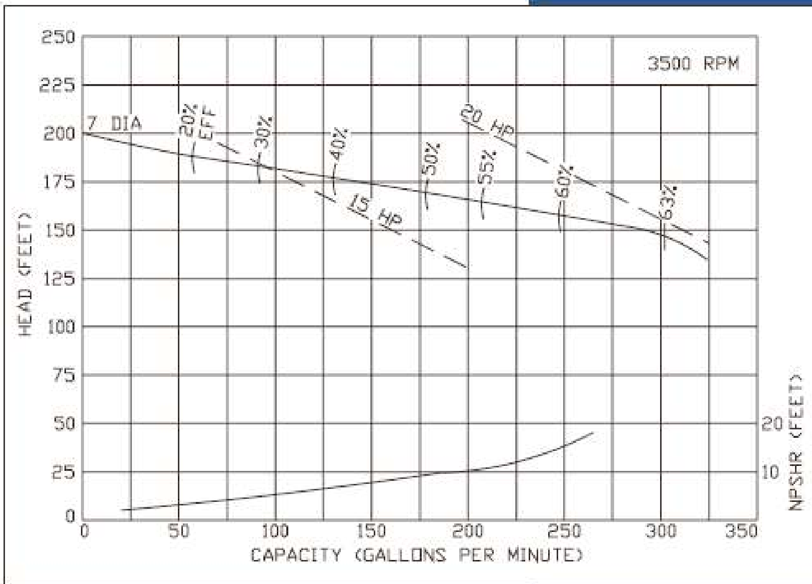
Ampco pumps are manufactured, assembled and tested in Glendale, Wisconsin USA.

Ampco Pumps Company

Ampco Pumps Company
2045 W. Mill Road
Glendale, WI 53209
Phone: 800.737.8671
Fax: 414.643.4452
sales@ampcopumps.com

www.ampcopumps.com

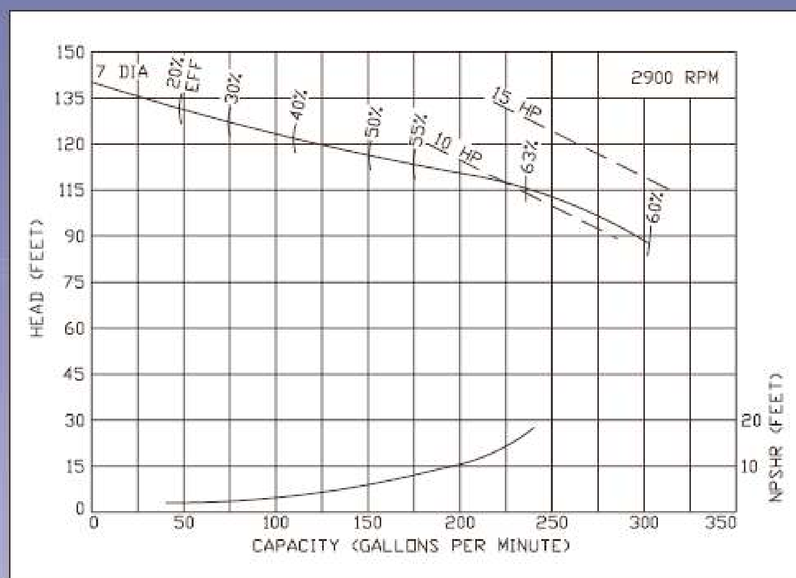
Ampco Pumps GmbH
Am Gäxwald 6
76863 Herxheim Germany
Phone: +49 7276 5058515
Fax: +49 7276 5058517
info@ampcopumps.de



Ampco Centrifugal Pumps

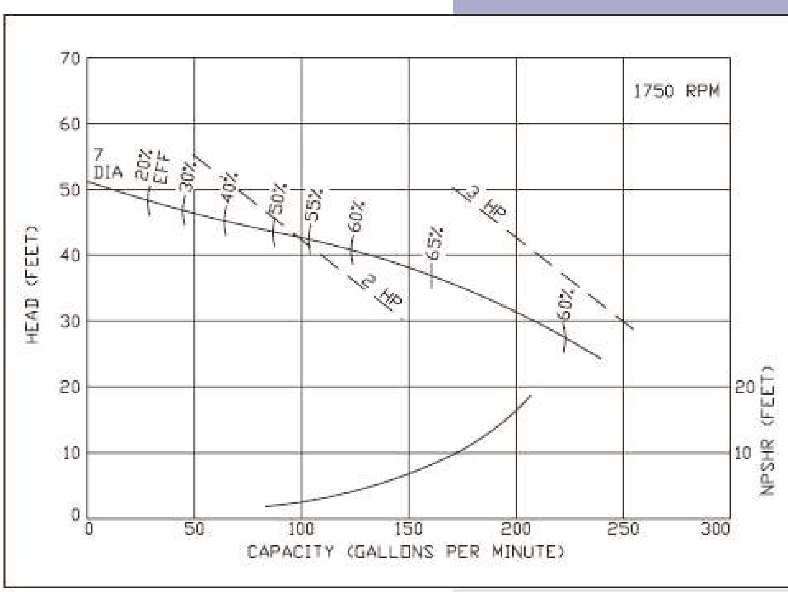
Model RC2/RCH2 3X3x7

Curves show approximate characteristics based on clear 68° water. Rated point is guaranteed.



RC2/RCH2 self-priming pumps are close coupled to JM frame motors and have NPT threaded connections.

Seal options include Type 21, Type 1 and Type 9 with choice of sealing materials.



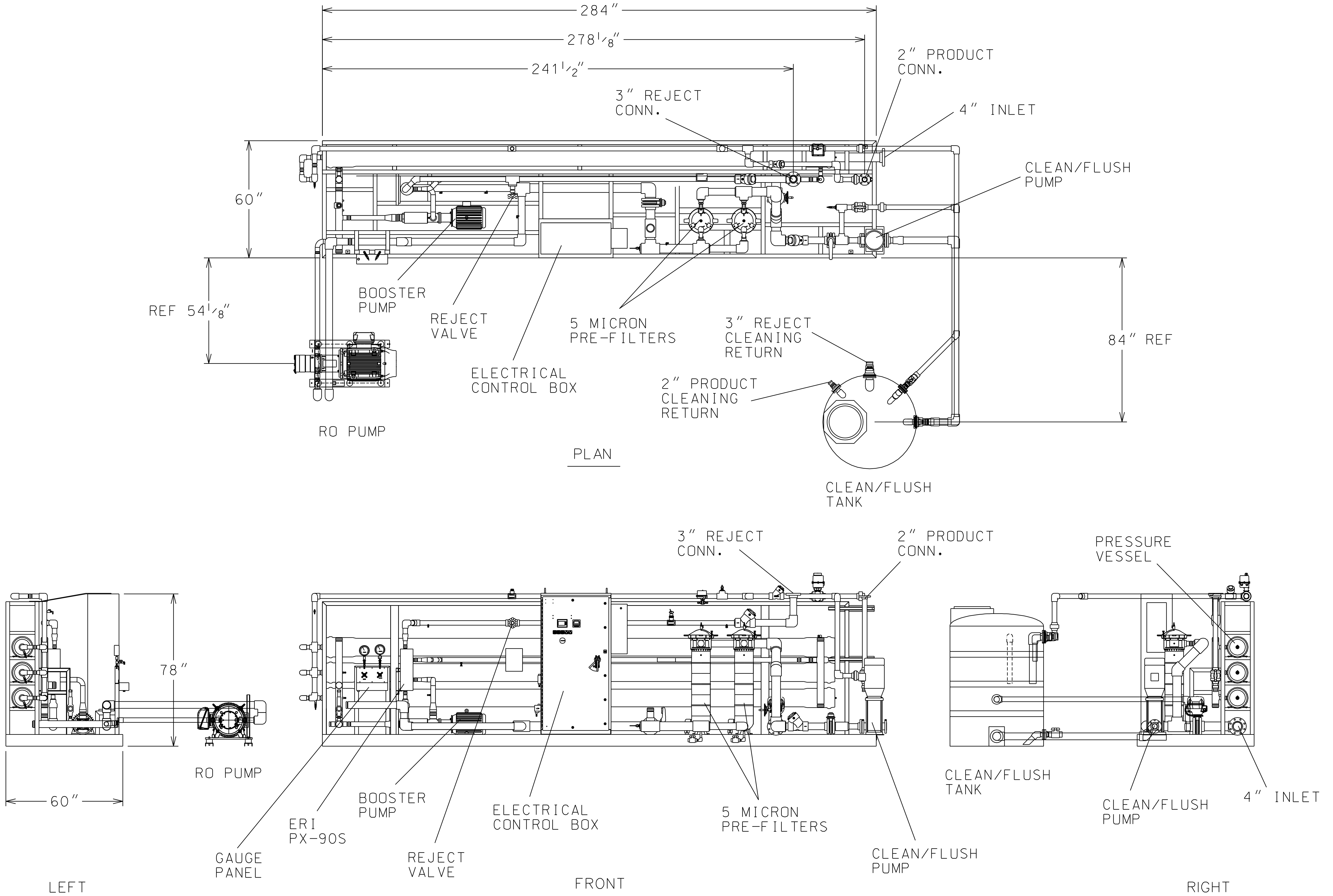
Ampco Pumps Company

4424 West Mitchell Street
Milwaukee, Wisconsin 53214
PHONE (414) 643-1852
FAX (414) 643-4452

Water Equipment Technologies
580 Village Blvd, Suite 310, W Palm Beach, FL 33409
TEL +1.561.684.6300 FAX +1.561.471.0629

Appendix F

Drawings



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REV	DATE	BY	

DRAWING NO. 3489-10

FILE: flowtronex/3489/mech/3489-10.dgn

DESIGN BY: RCC	SCALE: NONE
DRAWN BY: RCC	SHEET 1 OF 1
CHK'D BY: MJM	DATE: 30APR14

PROJECT: CARRIACOU

APPROVED: DATE:

TITLE: SW-13 M3/D REVERSE OSMOSIS UNIT LAYOUT

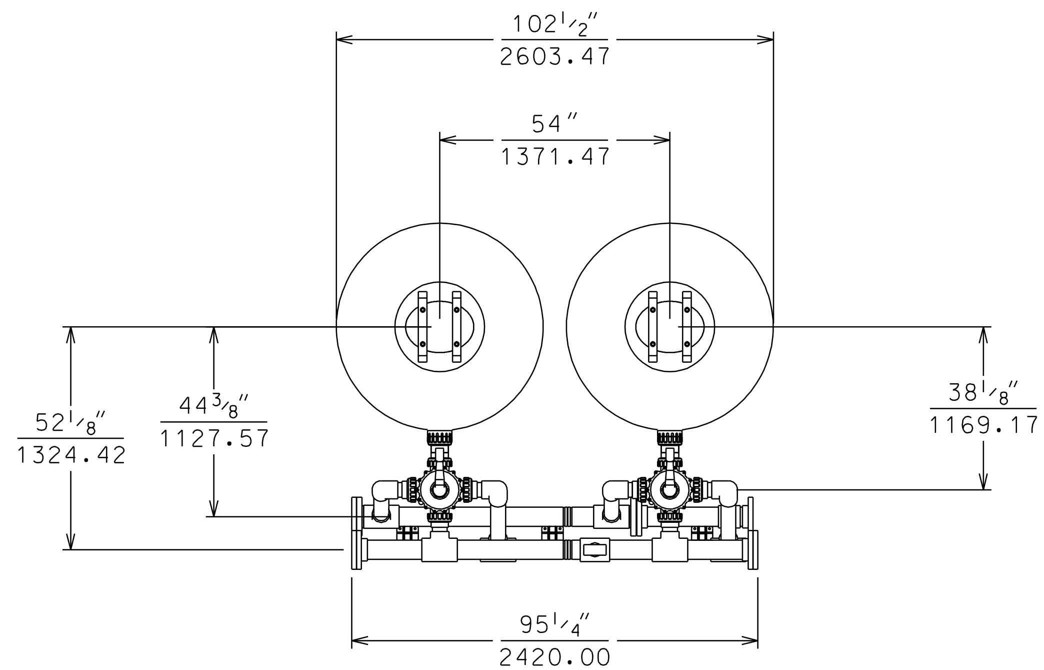
Water Equipment Technologies
a xylem brand

MULTI-MEDIA TANK LOADING		
MATERIAL	NUMBER OF BAGS	WEIGHT OF EACH BAG (LBS/KG)
1/2 X 1/4 GRAVEL	4	100/45.4
1/4 X 1/8 GRAVEL	3	100/45.4
#8 GARNET	6	50/22.7
SAND	16	100/45.4
ANTHRACITE	12	50/22.7

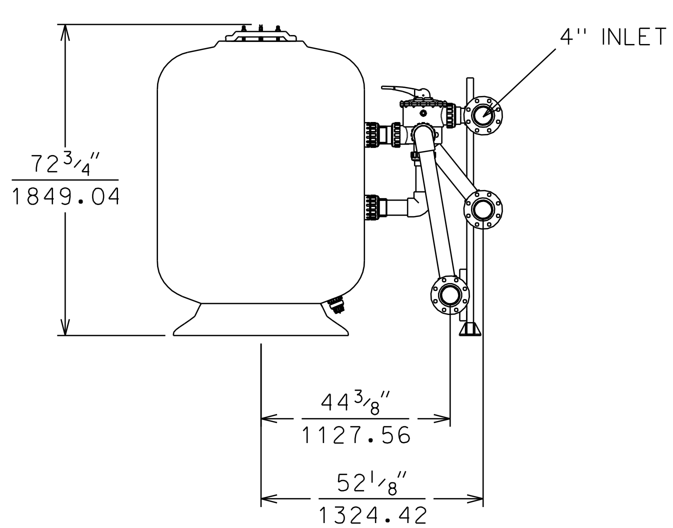
NOTE: WEIGHT OF BAGS MAY VARY. ADJUST NUMBER OF BAGS ACCORDINGLY.

QUANTITIES SHOWN ARE FOR LOADING EACH TANK

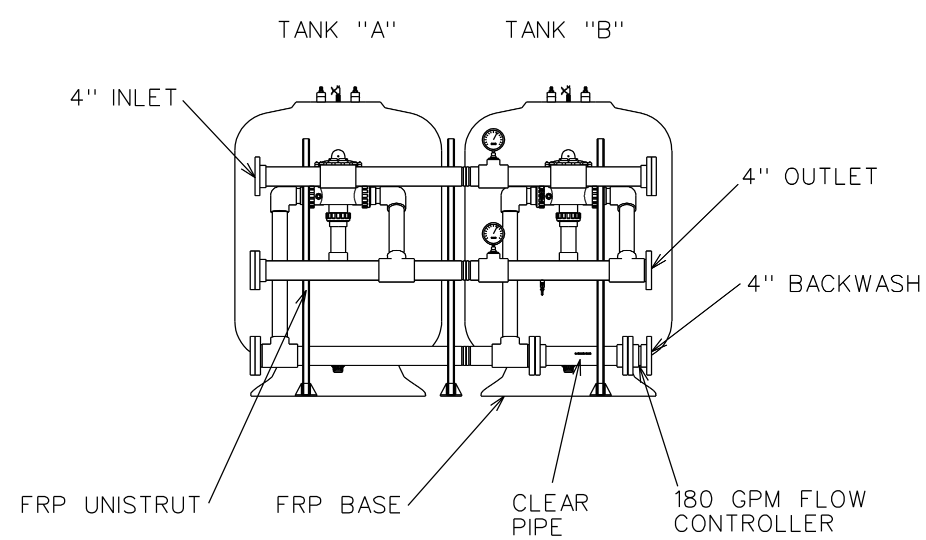
1. BACKWASH CYCLE PERFORMED ONE TANK AT A TIME.
2. ALL OTHER TANKS IN ARRAY TO REMAIN IN "NORMAL SERVICE".



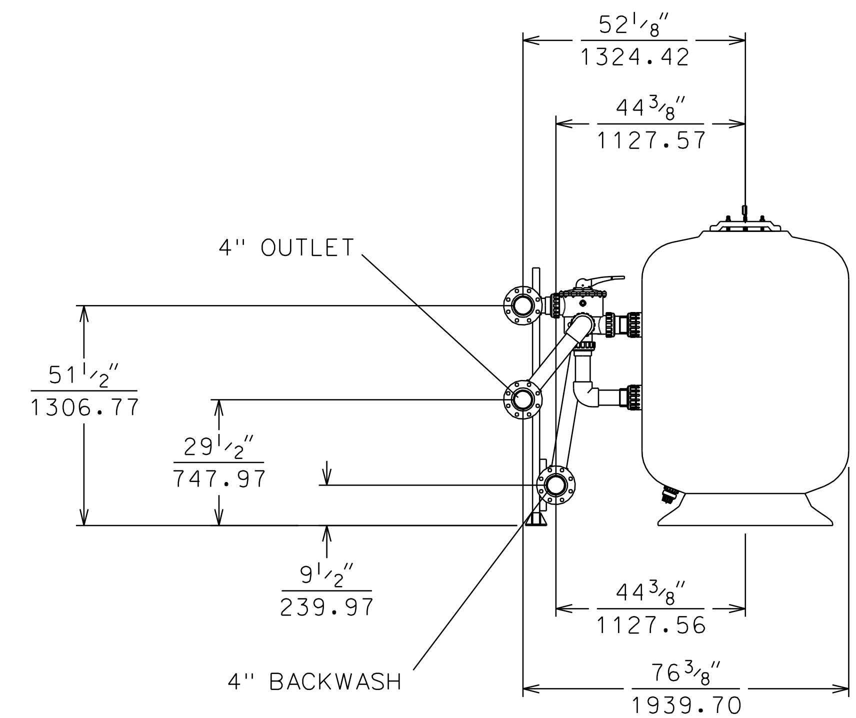
PLAN



LEFT SIDE



FRONT ELEVATION



RIGHT SIDE

REV	DATE	BY	DESCRIPTION

DRAWING NO. 3489-13

FILE: flowtronex\g003489\mech\3489-13.dgn

DESIGN BY: RCC SCALE: NONE

DRAWN BY: RCC SHEET 1 OF 1

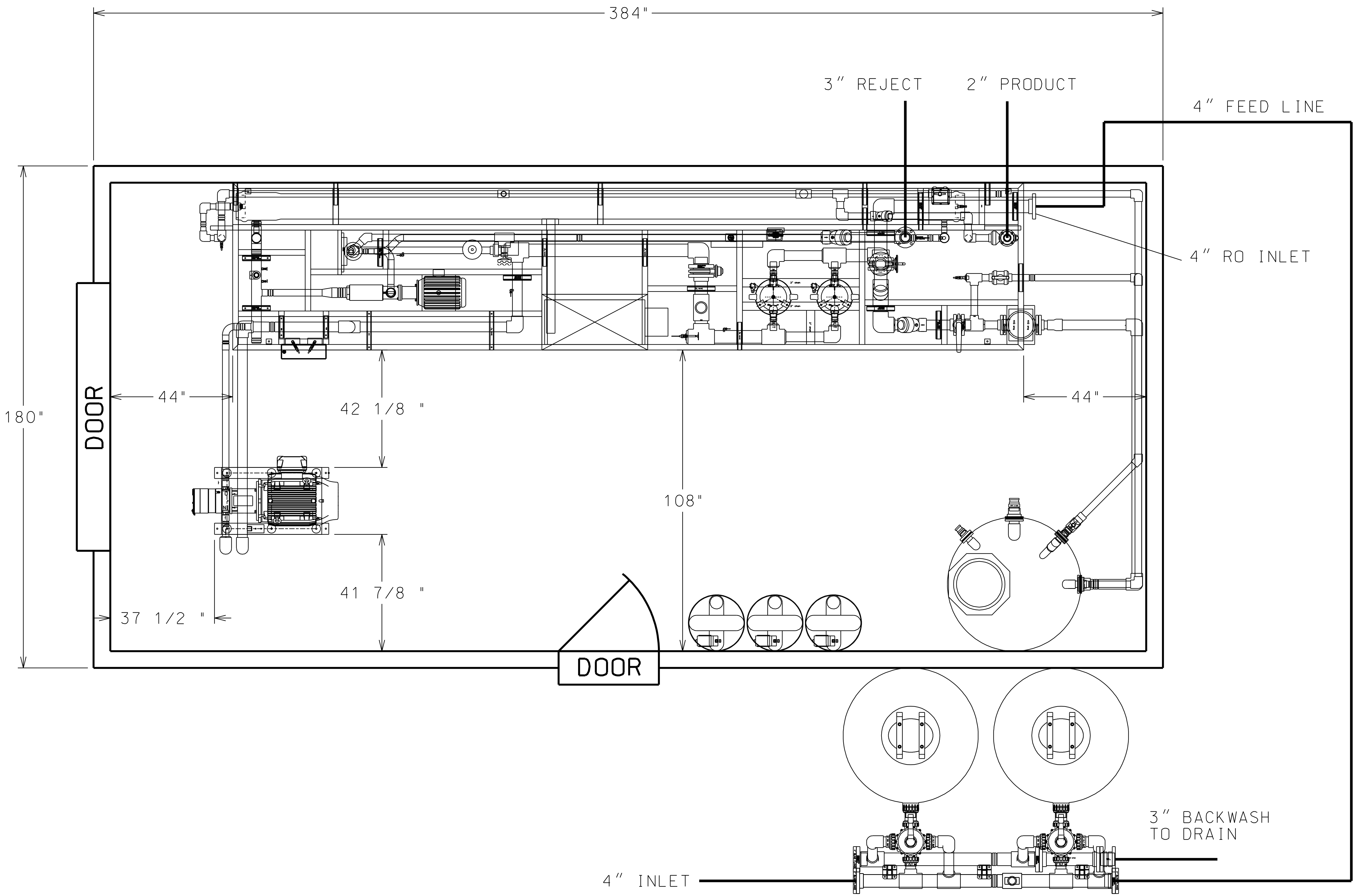
CHK'D BY: MJM DATE: 16JAN14

PROJECT CARRIACOU

APPROVED: DATE:

TITLE 48" MULTIMEDIA LAYOUT

Water Equipment Technologies a xylem brand



REV	DATE	BY	DESCRIPTION
A	20FEB14	RCC	MOVED MEDIA SYSTEM

DRAWING NO.

3489-24

FILE: cadd\micro dgn\a-z\border-d.dgn

DESIGN BY: RCC | SCALE: NONE

DRAWN BY: RCC | SHEET 1 OF 1

CHK'D BY: MJM | DATE: 19FEB14

PROJECT

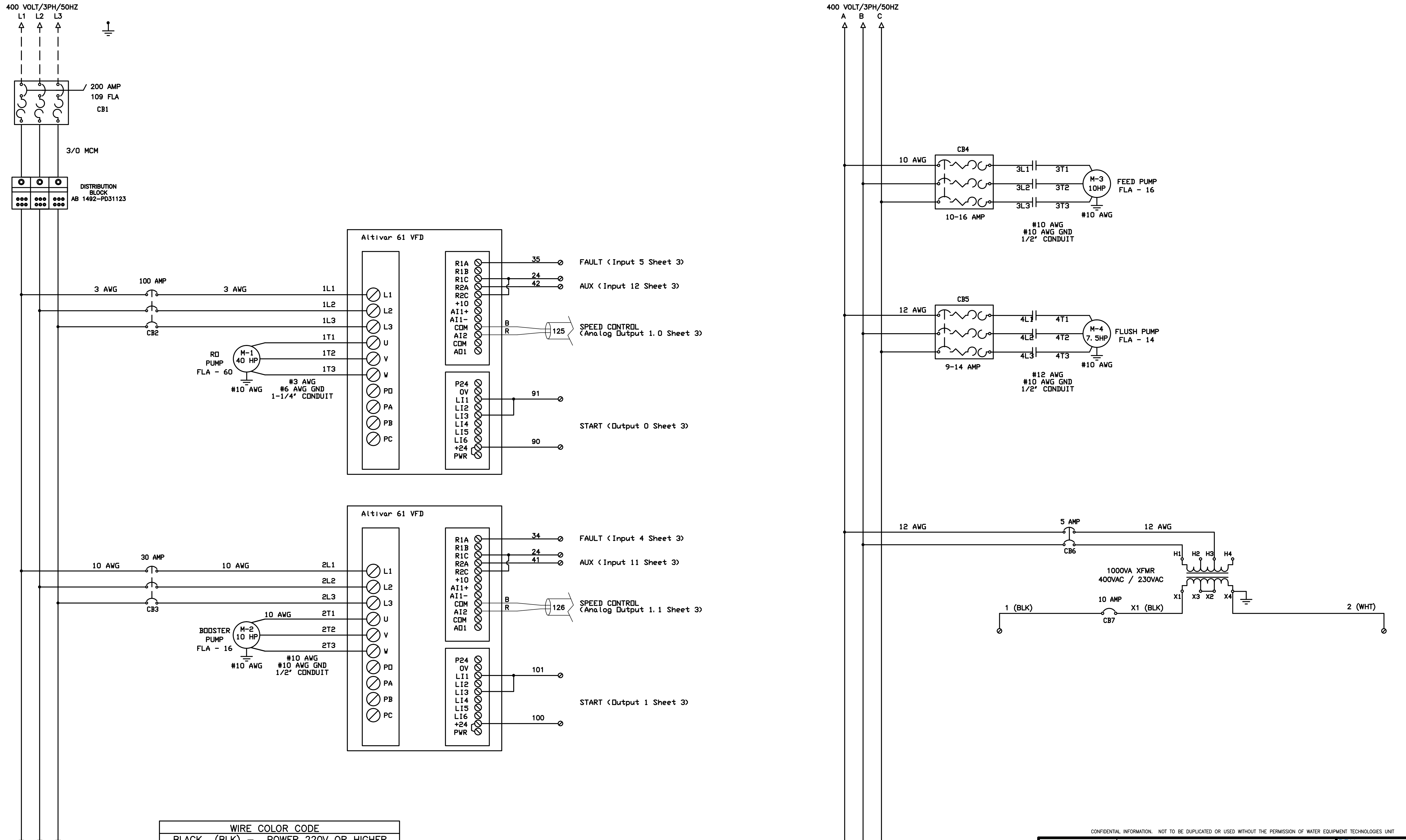
CARRIACOU
CWT

APPROVED: | DATE:

TITLE

SW-13M
REVERSE OSMOSIS
SYSTEM BUILDING
LAYOUT

Water Equipment Technologies
a xylem brand



WIRE COLOR CODE
BLACK (BLK) – POWER 220V OR HIGHER
WHITE (WHT) – NEUTRAL
GREEN (GRN) – GROUND
RED (RED) – AC CONTROL (110 V)
BLUE (BLU) – DC POSITIVE
WHITE W/BLUE (W/B) – DC NEGATIVE
YELLOW (YEL) – EXTERNAL SOURCE

REV	DESCRIPTION	DATE

REVISION HISTORY

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a xylem brand

10661 NEWKIRK STREET
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800.786.7480

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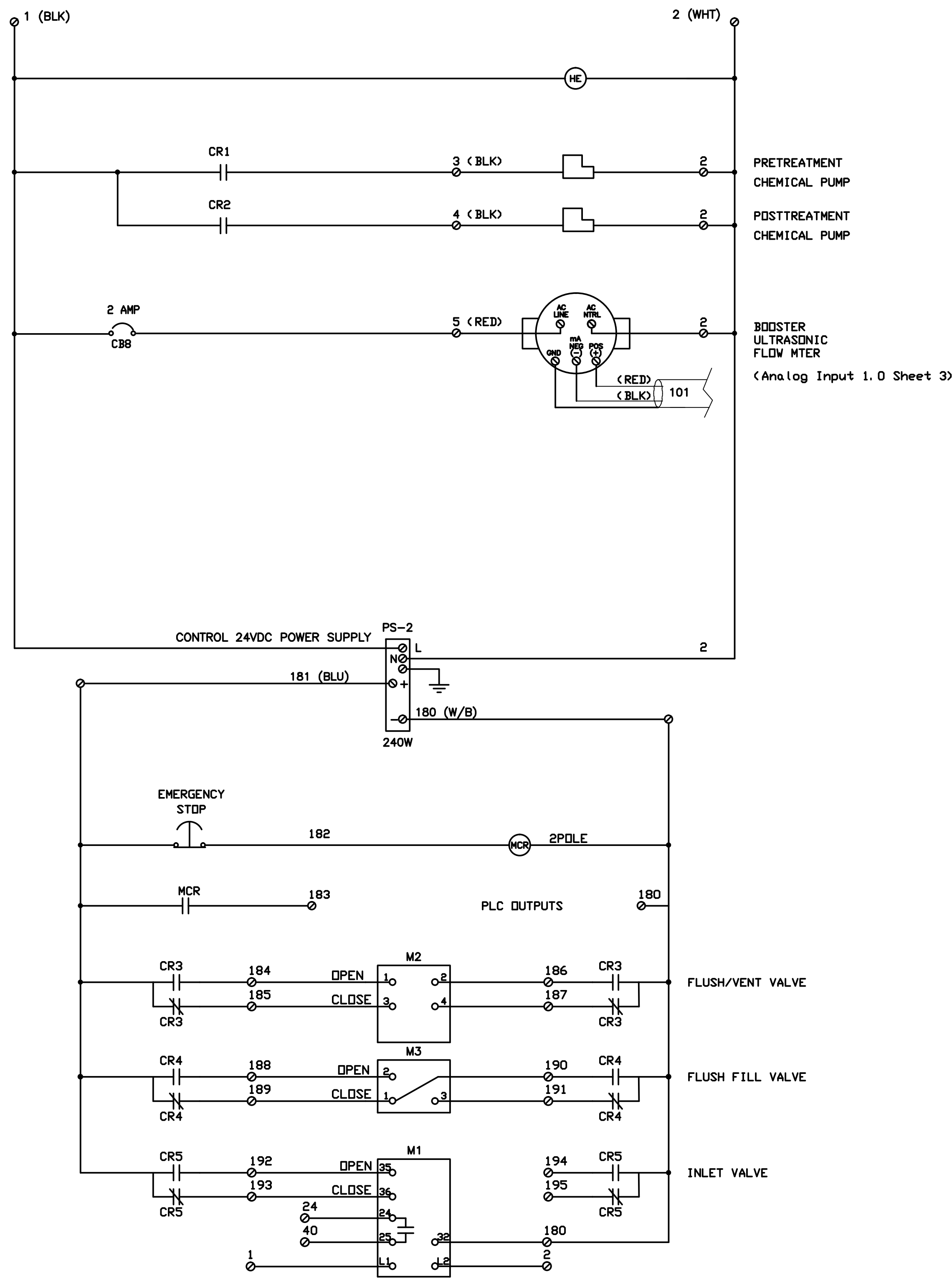
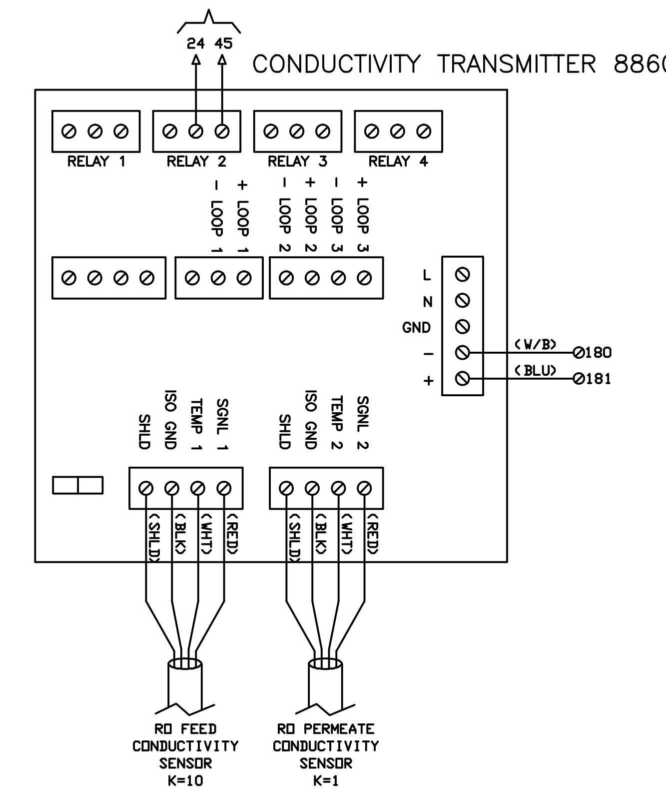
DRN: VN | DATE: 02/13/14
CHK: | DATE:
DRAWING #: G003489-3
DRAWING NAME: CARRIACOU CWT
SW-13M RO ELECTRICAL
SIZE B | REV 0 | SHEET: 1 OF 5





WIRE COLOR CODE			
BLACK	(BLK)	–	POWER 220V OR HIGHER
WHITE	(WHT)	–	NEUTRAL
GREEN	(GRN)	–	GROUND
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YELLOW	(YEL)	–	EXTERNAL SOURCE

REV	DESCRIPTION	DATE
	REVISION HISTORY	

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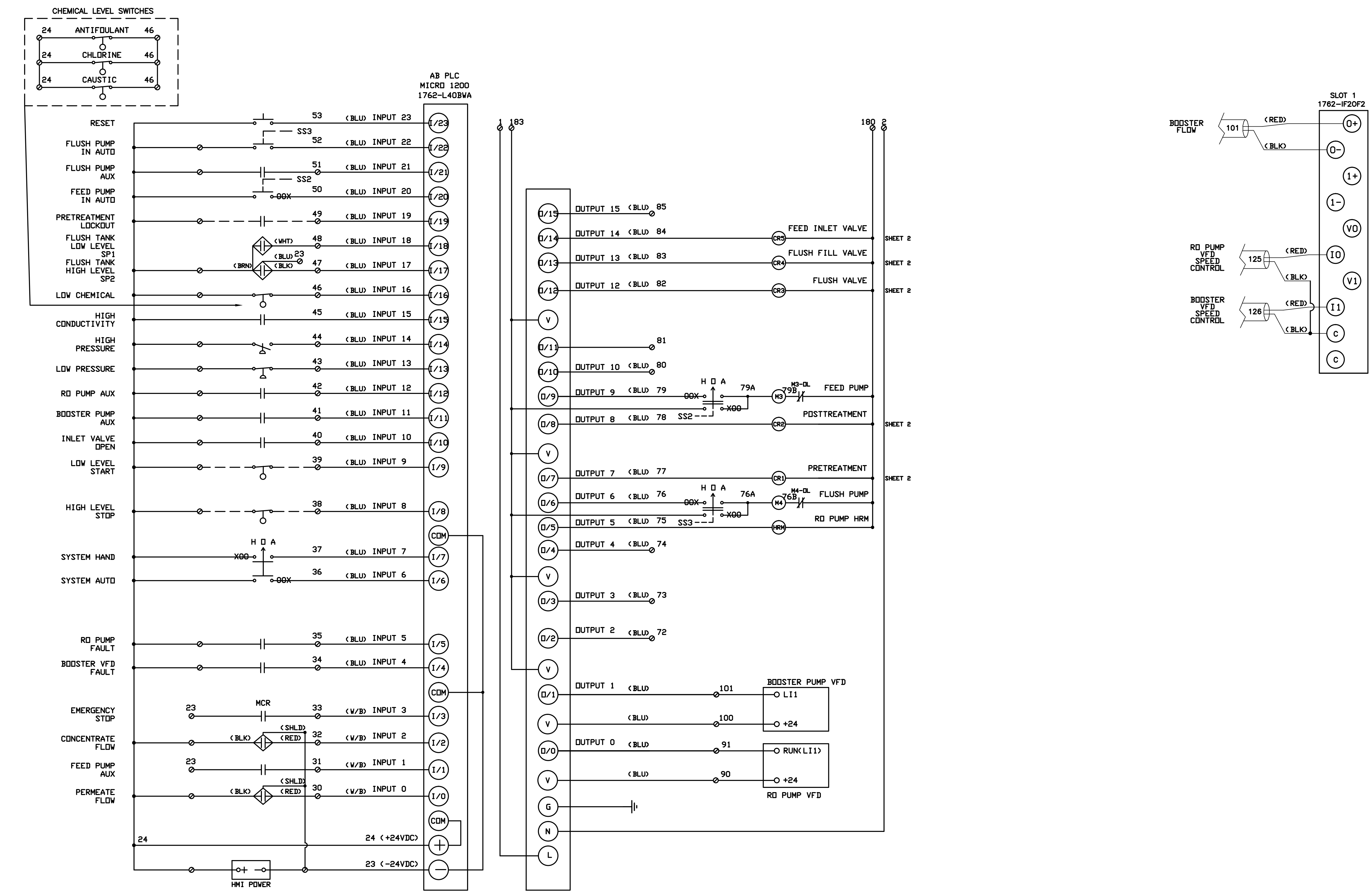
DRN: VN	DATE: 02/13/14
CHK:	DATE:
DRAWING #: G003489-3	
DRAWING NAME: CARRIACOU CWT SW-13M RO ELECTRICAL	
SIZE B REV 0	SHEET: 2 OF 5



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REV	DESCRIPTION	DATE
REVISION HISTORY		

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DALLAS, TX 75220
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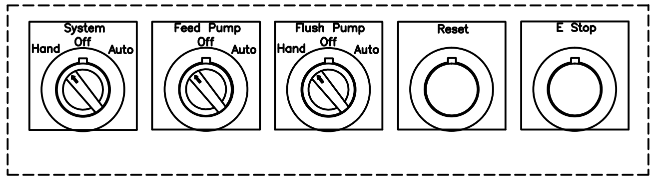
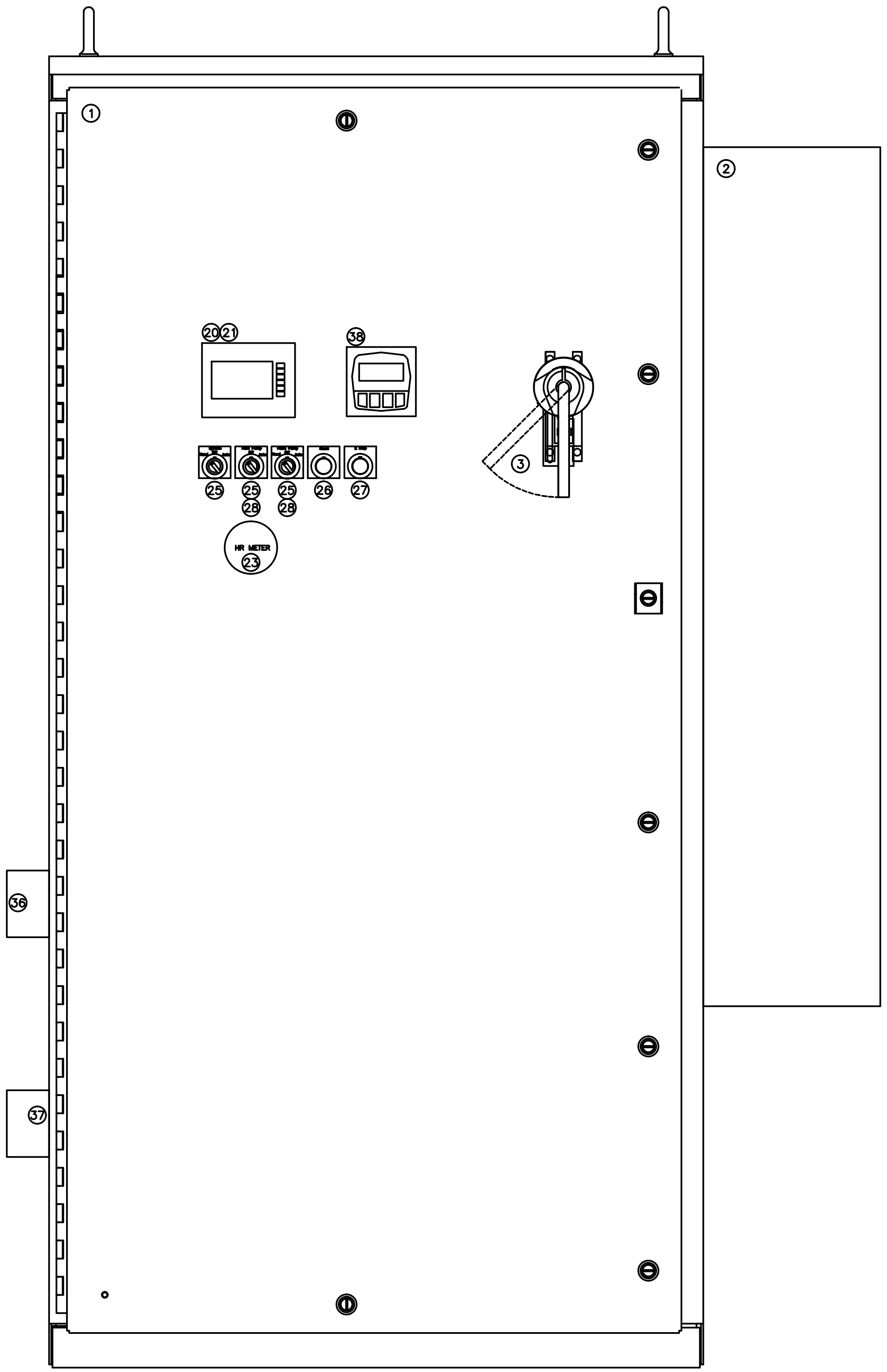
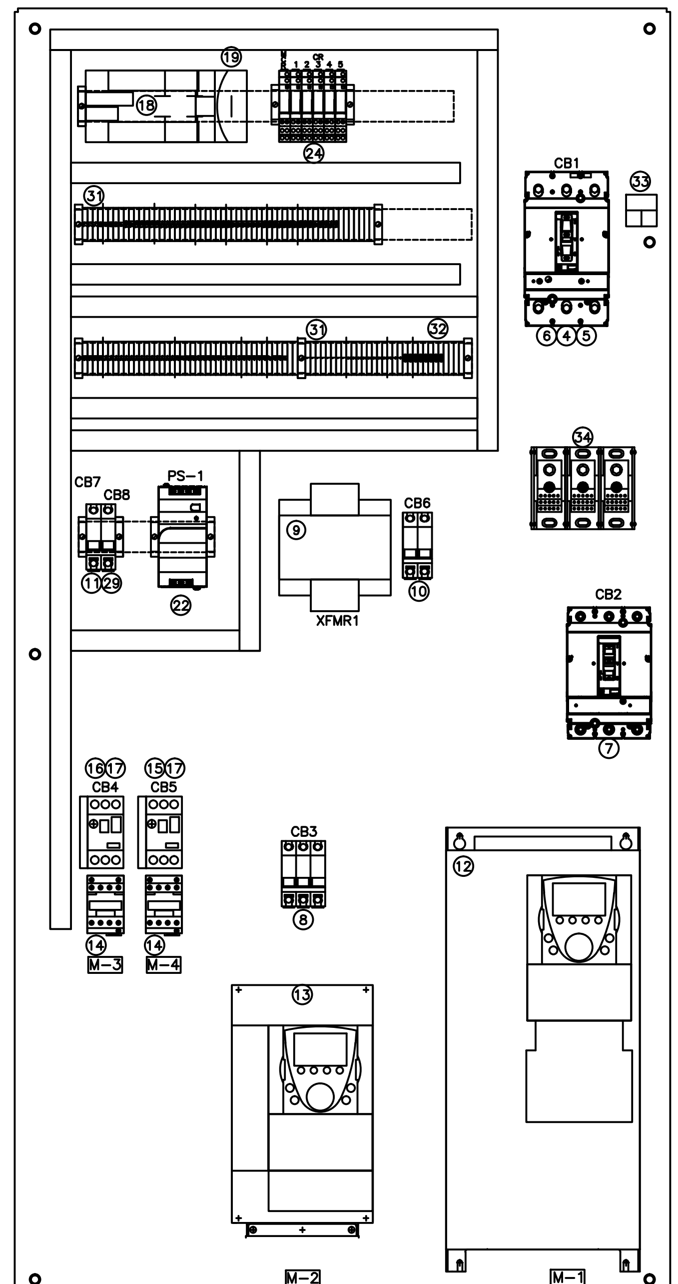
DRN: VN DATE: 02/13/14
CHK: DATE:
DRAWING #: G003489-3
DRAWING NAME: CARRIACOU CWT
SW-13M RO ELECTRICAL
SIZE B REV 0 SHEET: 3 OF 5

LEGENDS



Model Number	SM-13M		
Serial Number	G003489		
Voltage	400	SCCR	5KA
Phase	3	FLA	109
Hz	50	Max HP	40

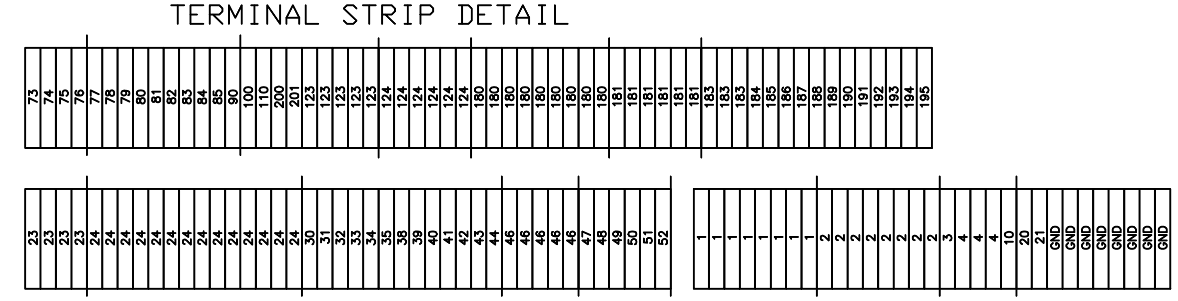




BILL OF MATERIALS

ITEM	QTY	PART #	DESCRIPTION
1	1	101-ENCL-G003489	ENCL,73X36X16,N4,AL,3.8 IN MAG,K2XNP47,RO
2	1	80-000-683	HEAT-EXCHGR,K2XNP47,230V,1.7A,56W DEGF
3	1	07-EL259421LC48	DISCON HANDLE TYPE 3,4 H&J SQD
4	1	07-EL259421LS13	DISCONNECT LONG SHAFT SQD
5	1	07-EL259421LJ7	DISCONNECT OPERATING MECH POWERPAC SQD
6	1	45-002-155	BRKR,CIR,200A,600V,3P,SQD,JDL36200
7	1	45-002-100	BRKR,CIR,100A,3P,SQD,HDL36100
8	1	07-EL04MG17472D	BREAKER 3-POLE 30A D MG SQD
9	1	07-EL289070T1000D33	CTRL TRANSFORMER 1000VA415-380VAC:115-23
10	1	07-EL04MG17454D	BREAKER 2-POLE 5A MG
11	1	07-EL04MG24432C	BREAKER CIRCUIT 1-POLE 10A MG SQD
12	1	07-EL30ATV61HD30N4	INVERTER VFD 30KW ATV61SQD
13	1	07-EL30ATV61HU75N4	INVERTER VFD 7.5KW ATV 61SQD
14	2	07-EL08LC1D25BL	CONTACTOR 3PH 25A 24VDC TELE
15	1	07-EL23GV2-ME16	STARTER MANUAL 9-14A TELE
16	1	07-EL23GV2-ME20	STARTER MANUAL 13-20 TELE
17	2	07-EL23GV-AD1010	STARTER MANUAL FAULT-AUX TELE
18	1	07-IN041762-L40BWAR	PLC PROCESSOR AB 1200 24DC-16R 2 PORT
19	1	07-IN041762-IF2OF2	PLC MODULE ANALOG COMB 2LN-2OUT AB 1200
20	1	84-001-601	HMI,MAGELIS,3.8 IN,COLOR,ETH,HMIGTO1310
21	1	07-IN04CBL1200-XBTGT1100	CABLE AB PLC - MAGELIS
22	1	07-EL19-001	POWER SUPPLY 120-240VAC 24VDC-240W-10 AB
23	1	81-001-033	HOUR METER, W-GASKET,60HZ, 10-80 VDC
24	6	07-EL700HLT12Z24	RELAY TERMINAL BLOCK 24VDC 10A 2POLE AB
25	3	07-EL25800FPSM32PX20	SWITCH 3 POS MAINT 2NO W-LATCH AB
26	1	07-EL25800FPF2PX10	SWITCH PUSH BUTTON BLK 1NO W- LATCH AB
27	1	07-EL25800FPMT34PX01	SWITCH 22MM PUSH-TWIST EMG 30MM W-LATCH-1NC AB
28	2	07-EL09800FX10	CONTACT BLOCK NO AB800F-X10
29	1	45-000-712	BRKR,CIR,2.0A,1P,AB,1492-SP1C020,2A,10KA
30			
31			
32	102		TERMINALS
33	8		TERMINAL GROUND
34	1		GROUND LUG
35	1	73-001-140	BLOCK,DISTRIB.,1492-PD31123
36			
37	1	07-EL25132P46C3	Switch Pres Neo-Dyn 132P-1500
38	1	07-EL25PH90	Switch Pres 3-90 PSI Poly
39			
40			
41			

TERMINAL STRIP DETAIL



WIRE COLOR CODE	
BLACK (BLK)	POWER 220V OR HIGHER
WHITE (WHT)	NEUTRAL
GREEN (GRN)	GROUND
RED (RED)	AC CONTROL (110 V)
BLUE (BLU)	DC POSITIVE
WHITE/BLUE (W/B)	DC NEGATIVE
YELLOW (YEL)	EXTERNAL SOURCE

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REV	DESCRIPTION	DATE
REVISION HISTORY		

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a xylem brand
10661 NEWKIRK STREET
DALLAS, TX 75220
800.786.7480

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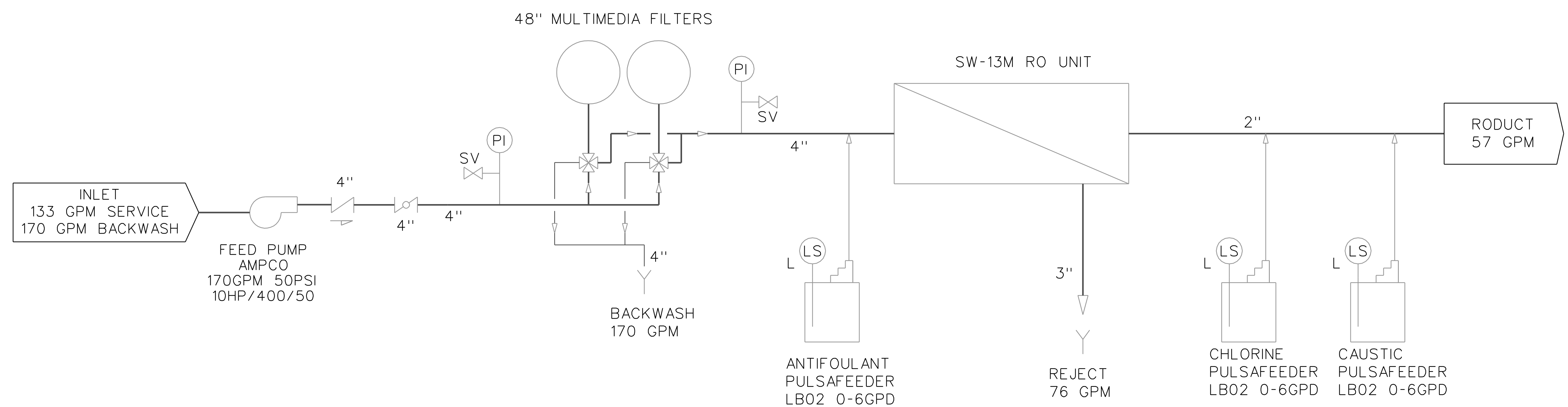
DRN: VN	DATE: 02/13/14
CHK:	DATE:
DRAWING #: G003489-3	
DRAWING NAME: CARRIACOU CWT SW-13M RO ELECTRICAL	
SIZE B	REV 0
SHEET: 4 OF 5	



A - ANALYTICAL	OOR - OUT OF RANGE	M_ - MOTORIZED OPERATOR	- BUTTERFLY VALVE	- 3 WAY BALL VALVE	- CENTRIFUGAL PUMP	H(X)- - HIGH ALARM	(XX)- - PANEL MOUNTED INSTRUMENT
C - CONDUCTIVITY	P - PRESSURE						
E - SENSOR	S - SWITCH	- PNEUMATIC OPERATOR	- BALL VALVE	- RELIEF VALVE	- POSITIVE DISPLACEMENT PUMP	L(X)- - LOW ALARM	- FLOW CONTROLLER
F - FLOW	SV - SAMPLE VALVE						
I - INDICATOR	T - TRANSMITTER	S - SOLENOID OPERATOR	- REGULATING VALVE	- FILTER/REGULATOR	- CHEM FEED PUMP	- CHEMICAL TANK MIXER	- ORIFICE PLATE
L - LEVEL	TI - TEMPERATURE						
ORP - OXIDATION REDUCTION POTENTIAL	V - VIBRATION	- FLEXIBLE CONNECTOR	- CHECK VALVE	- CLEANING CONNECTION		- STATIC MIXER	- SUCTION DISCHARGE/ ACCUMULATOR
	Δ - DIFFERENTIAL						

REV	DATE	BY	DESCRIPTION

DRAWING NO. 3489-9

FILE: flowtronex\3489\mech\3489-9.dgn | SCALE: NONE | SHEET 1 OF 1 | DATE: 15JAN14

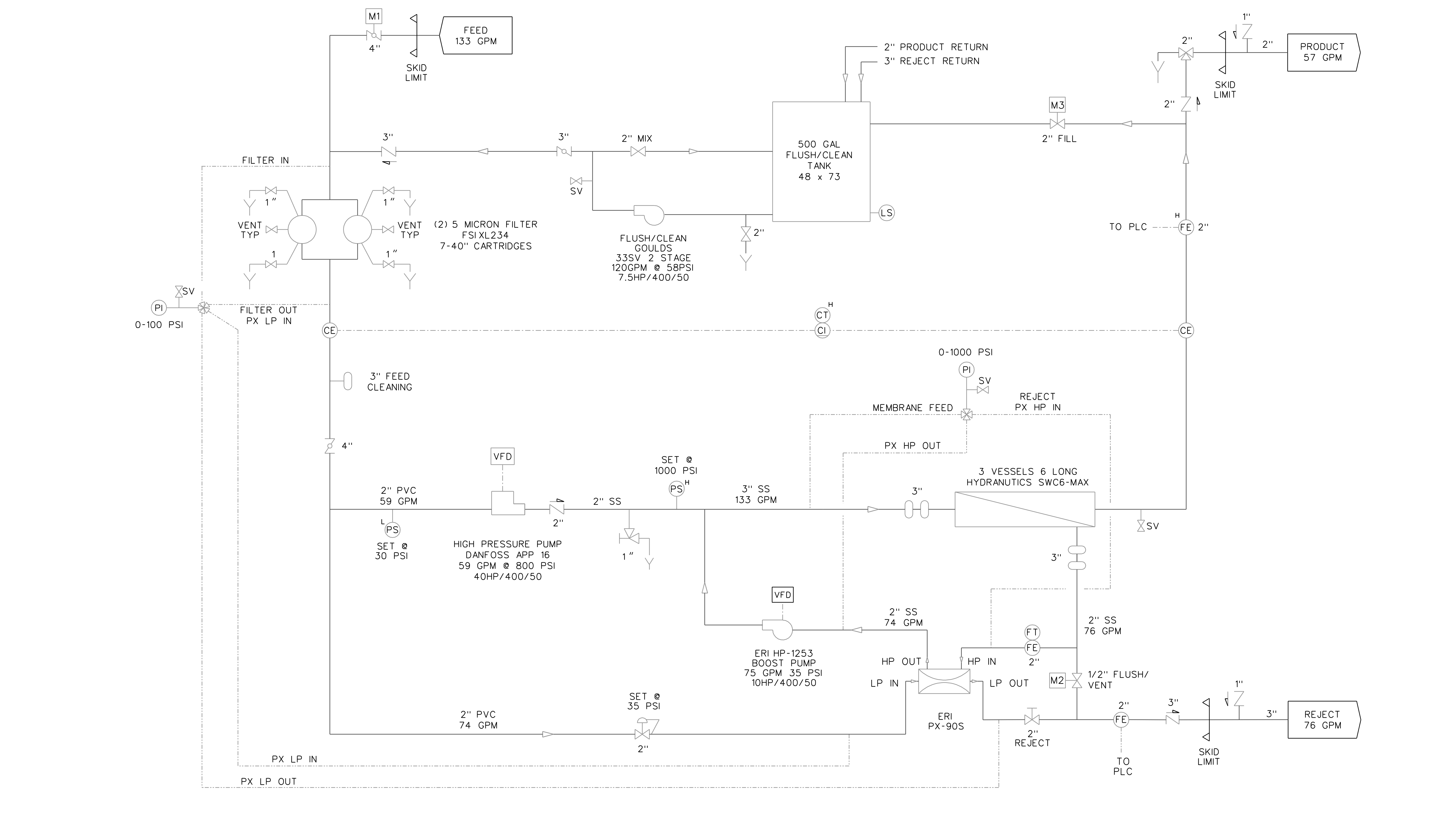
DESIGN BY: MJM | DRAWN BY: MJM | CHK'D BY: MJM

PROJECT: CARRIACOU CWT

APPROVED: | DATE:

TITLE: SW-13M REVERSE OSMOSIS SYSTEM P&I DIAGRAM

Water Equipment Technologies a xylem brand



A - ANALYTICAL	OOR - OUT OF RANGE	M_ - MOTORIZED OPERATOR	BUTTERFLY VALVE	3 WAY BALL VALVE	CENTRIFUGAL PUMP	HIGH ALARM	PANEL MOUNTED INSTRUMENT
C - CONDUCTIVITY	P - PRESSURE						
E - SENSOR	S - SWITCH	PNEUMATIC OPERATOR	BALL VALVE	RELIEF VALVE	POSITIVE DISPLACEMENT PUMP	LOW ALARM	FLOW CONTROLLER
F - FLOW	SV - SAMPLE VALVE						
I - INDICATOR	T - TRANSMITTER	S - SOLENOID OPERATOR	REGULATING VALVE	FILTER/REGULATOR	CHEM FEED PUMP	CHEMICAL TANK MIXER	ORIFICE PLATE
L - LEVEL	TI - TEMPERATURE						
ORP - OXIDATION REDUCTION POTENTIAL	V - VIBRATION	FLEXIBLE CONNECTOR	CHECK VALVE	CLEANING CONNECTION		STATIC MIXER	SUCTION DISCHARGE/ ACCUMULATOR
	Δ - DIFFERENTIAL						

DESCRIPTION | BY | DATE | REV

DRAWING NO. 3489-2

FILE: flowtronex\3489\mech\3489-2.dgn | SCALE: NONE | SHEET 1 OF 1 | DATE: 15JAN14

DESIGN BY: MJM | DRAWN BY: MJM | CHK'D BY: MJM

PROJECT: CARRIACOU CWT

DATE: | APPROVED:

TITLE: SW-13M REVERSE OSMOSIS UNIT P&I DIAGRAM

Water Equipment Technologies a xylem brand