About Pump Engineering, Inc.

Pump Engineering, Inc. (PEI) was founded in 1986 for the purpose of developing and manufacturing advanced technology pumps. Since 1988 the company has focused its efforts on providing the reverse osmosis industry with the most efficient and lowest total life cycle cost energy recovery equipment. PEI Hydraulic Turbocharger has become the most widely used ERT in the world for RO service.

Now in its third generation with the AT Turbocharger and the new LPT Turbocharger, PEI has continued to invest its interest and energy in delivering to the RO user a new level of performance and efficiency. The AT and LPT lines are the latest effort in our policy of continuous improvement in products and services. Designed specifically for lower pressure BWRO service, the LPT line represents a new level of custom engineered turbocharger product made possible by recent advances in computational fluid dynamics software, 3D CNC machining software, and 5 axis CNC machining.

Located in Monroe, Michigan, USA, thirty miles south of the Detroit, PEI is at the center of the largest concentration of manufacturing activity in the United States. PEI strives for excellence in the manufacturing arts and draws of the experience of generations of talented people who have passed down the traditions of craftsmanship.

About the LPT Turbo

The LPT Turbo recovers hydraulic energy from the high pressure concentrate (brine) stream in the reverse osmosis (RO) process and transfers that energy to the feed stream. The concentrate from either the 2^{nd} or 3^{rd} stage of a multi-stage system drives a trubine, which drives a direct coupled "booster" pump impeller in the stream feeding either the 2^{nd} or 3^{rd} stages respectively.

This unique approach offers many advantages to the RO designer and users. This manual will explain in detail these advantages and innovations that make the LPT the most efficient and cost effective energy recovery unit available today for this service. The manual shows how to estimate Turbo performance as well as how to apply the Turbo to multistage RO systems.

Table of Contents

LPT Turbo Background

The LPT Turbo transfers pressure energy from one liquid stream to a second liquid stream. The two streams may be at different pressure and flow rates.

The LPT Turbo consists of a pump section and a turbine section. Both pump and turbine sections contain a single stage impeller or rotor. In the reverse osmosis process the turbine rotor extracts hydraulic energy from the brine stream and converts it to mechanical energy. The pump impeller converts the mechanical energy back to pressure energy in the feed stream. Thus, the LPT Turbo is entirely energized by the concentrate stream. It has no electrical, external lubrication, or pneumatic requirements.

Pictured above: LPT-500

Design and Operating Features

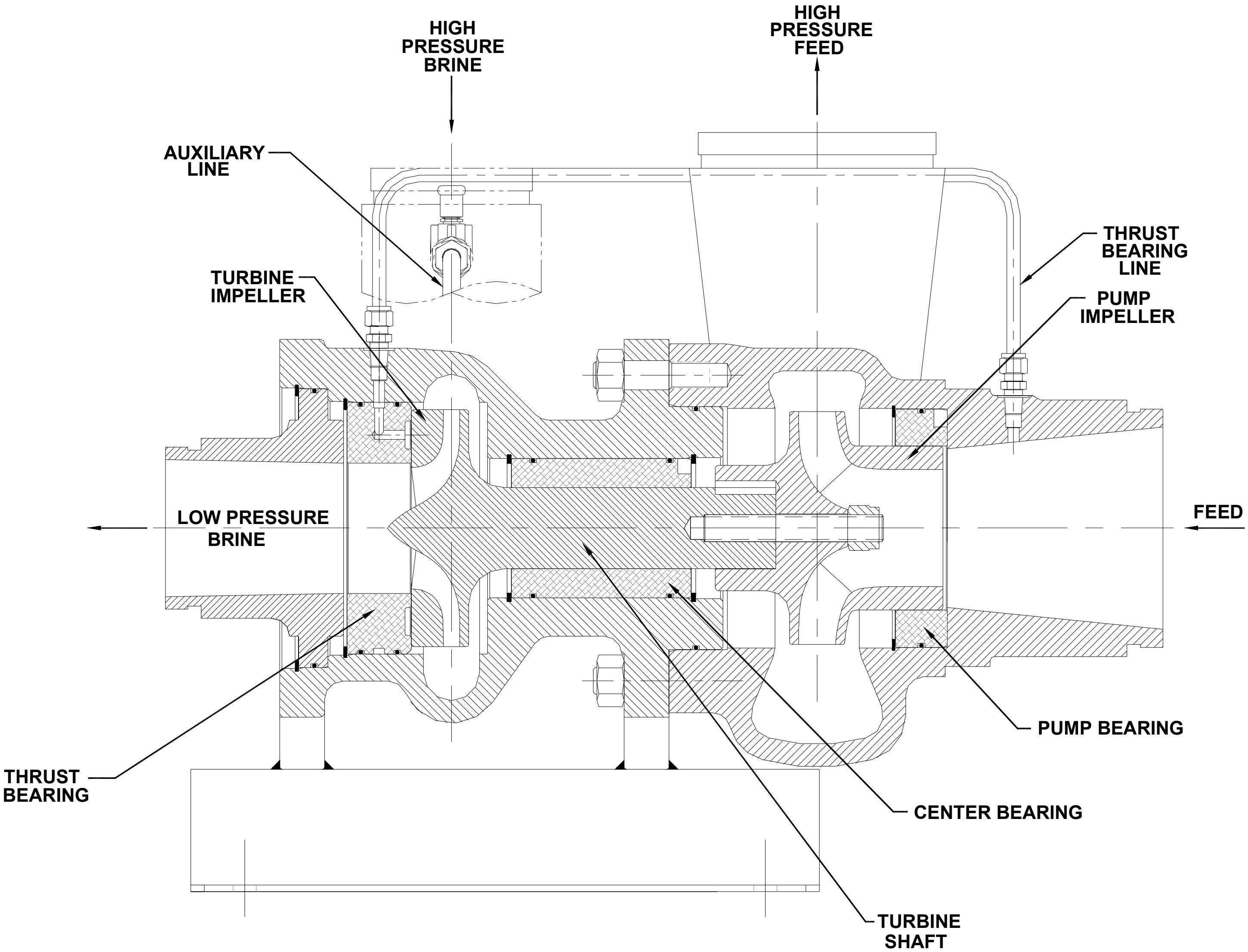
1. Combines energy recovery turbine and interstage booster pump in single unit
2. Turbo boost compensates for pressure losses in 1st stage
3. Turbo boost compensates for increased osmotic pressure in 2nd stage
4. Balance permeate flux rates between stages
5. Reduces overproduction in 1st stage which can result in concentration polarization without resorting to permeate backpressure
6. Can reducing fouling potential of 1st stage
7. Entirely energized by brine pressure – no electrical components, consumption, or cost. By far the lowest Life Cycle Cost pump for interstage booster service
8. Hydrostatic thrust bearing and no mechanical seal design insure reliable trouble free operation at high suction pressures typical of intestage booster application.
9. Zero scheduled maintenance – water lubricated bearings
10. Pump discharge and turbine inlet nozzle connections can be rotated 360 degrees for maximum installation flexibility
11. Small space requirement
12. Low noise and vibration
13. Able to discharge concentrate against backpressure on turbine
14. Brine is not exposed to the atmosphere, thereby minimizing odor and corrosion problems
15. Both turbine and pump impellers are specifically designed and manufactured using CFD & 5-axis machining, for utmost efficiency.

Materials of Construction:

The LPT Turbocharger is offered with three options for materials of construction –

SS304
SS316
Duplex Stainless Steel Alloy 2205.

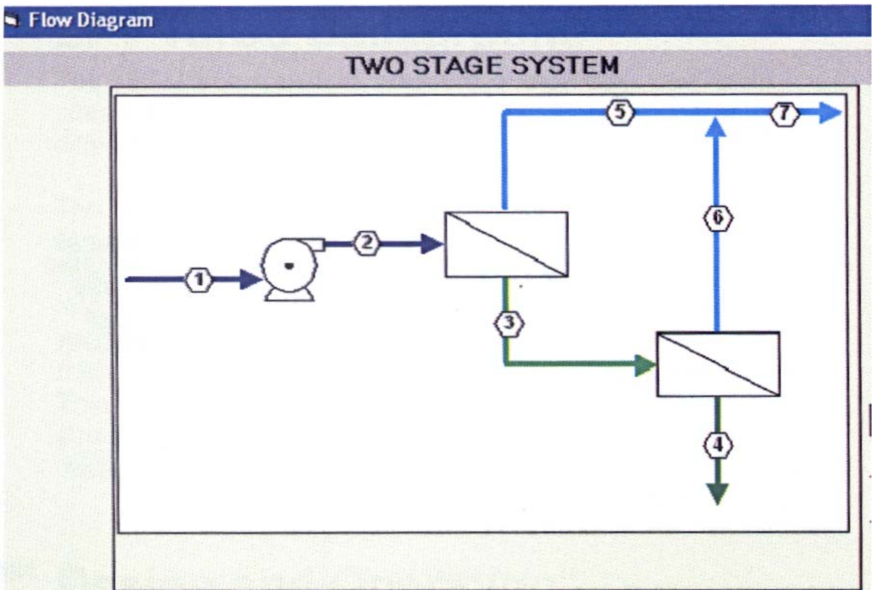
Depending on pressure and salinity (corrosion) consideration the customer can specify the material that is right for their particular application.



Construction Features

1. Casings are designed for a maximum of 600 psi operating pressure. Turbine casing volutes are machined for high efficiency and correct turbine differential pressure.
2. Impellers are complex geometry 3D type, custom designed for the specific application and produced on a 5axis CNC milling machine. All impellers are dynamically balanced to ISO G3 high speed spindle tolorances
3. Dynamically Balanced Impellers precision cast for maximum efficiency.
4. Product lubricated journal bearings eliminate shaft seals and oil/grease lubrication and provide years and years of maintenance free operation.
5. Hydrostatic Thrust Bearing - Product lubricated thrust bearing allows turbine to run with 98% volumetric efficiency.
6. RO Standard Victaulic Pipe Connections insure reliable leak free service.
7. Heavy duty stiff shaft design operates below critical speed insuring minimum vibration levels.
8. Radially split casing for complete and easy access for maintenance.
9. Circumfrential mounting allows complete rotation of turbocharger pipe connections for easy piping fit up.
10. Patented Design - Interstage Pressure Boosting of a multi-stage RO system is covered by PEI patent U.S. 4,983,305.
11. Pump Casings are designed for a range of cast volutes achieving high efficiency throughout the capacity range.

Two Stage System Analysis



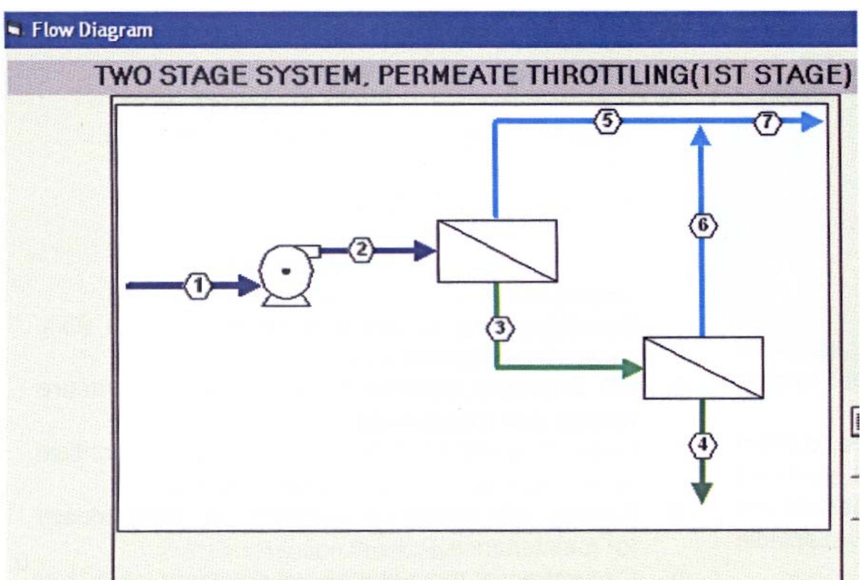
		1	2	3	4	5	6	7
Flow	gpm	1282.1	1282.1	474.3	282.1	807.7	192.3	1000.0
Pressure	psi	0.0	320.2	300.6	280.1	0.0	0.0	0.0
TDS (ppm)		4260.0	4251.8	11360.4	18879.0	77.0	332.6	126.1

Calculation Results — Pressure: psi; Flow/vessel: gpm; gfd

Array	Vessels	Feed	Conc.	Feed	Conc	Flux	Beta
1-1	28	320.2	300.6	45.8	16.9	17.3	1.20
1-2	13	300.6	280.1	36.5	21.7	8.9	1.07
1-3	0	0.0	0.0	0.0	0.0	0.0	0.00
1-4	0	0.0	0.0	0.0	0.0	0.0	0.00

Case A - Two Stage System - No Permeate Throttling

Pump Type	VTP12SKH
High Pressure Pump hp	267 hp
Number of Stages	12
Motor & VFD size	300 hp
High Pressure Pump kW	216
Permeate Energy Rate kW/1,000 gal	3.6
Annual kW usage @8000 hrs/year	1,728,000
Annual kW cost @$.06/kW	**$103,680**
Annual Penalty in unrecovered energy	**$14,157**
1st Stage Flux Rate	17.3
2nd Stage Flux Rate	8.9
Permeate Quality	126 TDS
Capital Cost	
HP Pump	$112,456
Motor	$15,818
Motor Controller (VFD)	$19,730
Total:	**$148,004**



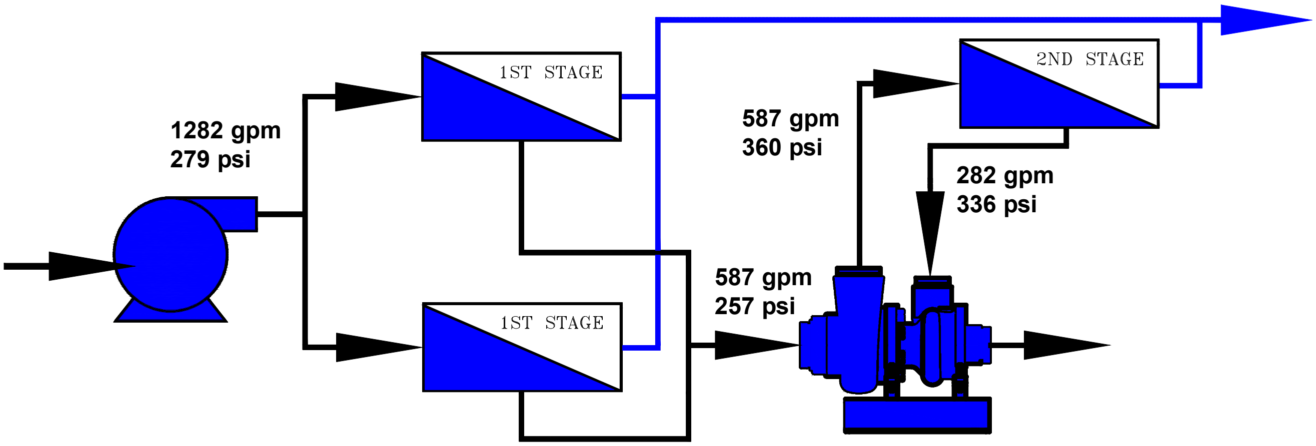
		1	2	3	4	5	6	7
Flow	gpm	1282.1	1282.1	587.7	282.1	694.4	305.6	1000.0
Pressure	psi	0.0	382.5	360.9	336.8	103.0	0.0	0.0
TDS (ppm)		4260.0	4251.8	9180.0	18924.4	80.6	187.6	113.3

Calculation Results — Pressure: psi; Flow/vessel: gpm; gfd

Array	Vessels	Feed	Conc.	Feed	Conc	Flux	Beta
1-1	28	382.5	360.9	45.8	21.0	14.9	1.14
1-2	13	360.9	336.8	45.2	21.7	14.1	1.11
1-3	0	0.0	0.0	0.0	0.0	0.0	0.00
1-4	0	0.0	0.0	0.0	0.0	0.0	0.00

Case B - Two Stage System - With Permeate Throttling

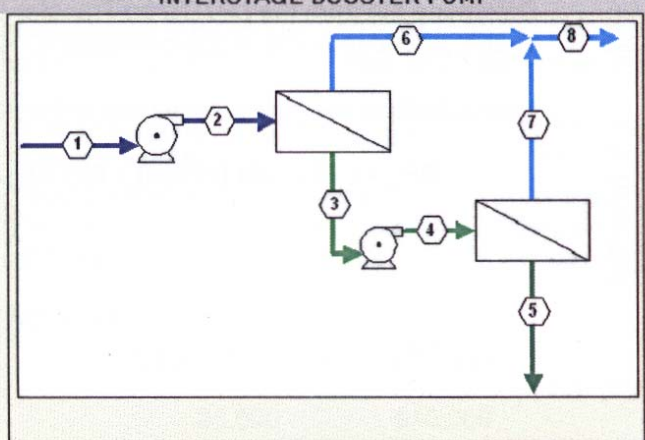
Pump Type	VTP12SKH
High Pressure Pump hp	320 hp
Number of Stages	14
Motor & VFD size	350 hp
High Pressure Pump kW	259
Permeate Energy Rate kW/1,000 gal	4.3
Annual kW usage @8000 hrs/year	2,072,000
Annual kW cost @$.06/kW	**$124,320**
Annual Penalty in unrecovered energy	**$34,797**
1st Stage Flux Rate	14.9
2nd Stage Flux Rate	14.1
Permeate Quality	113 TDS
Capital Cost	
HP Pump	$128,149
Motor	$24,448
Motor Controller (VFD)	$26,780
Total:	**$179,377**



Case C - Two Stage System
Utilizing the PEI LPT Energy Recovery Device
for Interstage Pressure Boosting

Flow Diagram

INTERSTAGE BOOSTER PUMP



		1	2	3	4	5	6	7	8
Flow	gpm	1282.1	1282.1	587.8	587.8	282.1	694.3	305.7	1000.0
Pressure	psi	0.0	279.4	257.8	360.8	336.7	0.0	0.0	0.0
TDS (ppm)		4260.0	4251.8	9178.8	9178.8	18924.6	80.6	187.6	113.3

Calculation Results — Pressure: psi; Flow/vessel: gpm; gfd

Array	Vessels	Feed	Conc.	Feed	Conc	Flux	Beta
1-1	28	279.2	257.6	45.8	21.0	14.9	1.14
1-2	13	361.1	337.0	45.3	21.7	14.1	1.11
1-3	0	0.0	0.0	0.0	0.0	0.0	0.00
1-4	0	0.0	0.0	0.0	0.0	0.0	0.00

Pump Type	VTP12SKH
High Pressure Pump hp	230 hp
Number of Stages	11
Motor & VFD size	250 hp
High Pressure Pump kW	187
Permeate Energy Rate kW/1,000 gal	3.11
Annual kW usage @8000 hrs/year	1,492,064
Annual kW cost @$.06/kW	**$89,523**
Annual Penalty in unrecovered energy	**$0**
1st Stage Flux Rate	14.9
2nd Stage Flux Rate	14.1
Permeate Quality	113 TDS
Capital Cost	
HP Pump	$102,162
Motor	$13,445
Motor Controller (VFD)	$17,156
LPT	$28,458
Total:	**$161,219**

LPT Payback Time
Case A - 11.15 months
Case B - 0 months

The Benefits of Interstage Pressure Boosting with the LPT

Manufactures of high rejection low pressure membranes often recommend the use of interstage boosting for reducing overall energy consumption, balancing permeate flux rates between stages, and improving water quality. To understand how the LPT can impact BWRO design, three design cases will be reviewed. Case A, B, and C show three configurations of a BWRO plant. Case A is a non boosted non permeate throttled base design. Case B employs permeate throttling for permeate flux balancing and Case C uses the LPT as an energy recovery turbine/interstage booster pump.

Looking at the data from the LPT boosted design, it is readily apparent that the LPT provides significant economic and operational advantages. Balanced permeate flux rates, over $34,000 per year in energy recovery savings, and reduced capital cost are all possible with the LPT. The LPT is the most cost effective design option for nearly all low pressure BWRO and ultrapure RO systems.

Turbo™ Performance

Generally an energy recovery turbine (ERT) is rated as having a certain efficiency based on the conversion of hydraulic energy into mechanical shaft energy. However, in RO where the process is driven by **pressure** energy, the shaft energy generated by the ERT is normally transferred to the feed pump which then converts that energy back into pressure energy in the feed stream.

Thus, a better measure of ERT efficiency for RO systems is the ratio of hydraulic energy returned to the feed stream to the amount available in the brine stream. This ratio is called the **hydraulic energy transfer efficiency**, or $\mathbf{h}_{te}$, and is defined as:

$\mathbf{h}_{te} = \mathbf{H}_{out} / \mathbf{H}_{in}$ [1]

Where $\mathbf{H}_{out}$ = Hydraulic energy transferred to the feed stream

$\mathbf{H}_{in}$ = Hydraulic energy available in the brine stream

The Hydraulic energy transfer efficiency provides the most accurate way to evaluate the energy recovery effectiveness of ERT's including the Turbo™.

Unlike conventional ERT's, the energy transfer efficiency of the Turbo™ is independent of feed pump efficiency. Figure 3 can be used to find the approximate hydraulic energy transfer efficiency for the Turbo™. For example, at a feed flow of 500 gpm the Turbo™ displays about a 63% transfer efficiency.

Knowing $\mathbf{h}_{te}$ makes calculation of the Turbo™ pressure boost, $\mathbf{DP}_{tc}$, very simple:

$$\mathbf{DP}_{tc} = (\mathbf{h}_{te})\,(\mathbf{R}_r)\,(\mathbf{P}_r - \mathbf{P}_e) \qquad [2]$$

Where $\mathbf{R}_r$ = ratio of brine flow to feed flow

$\mathbf{P}_r$ = brine pressure to Turbo™

$\mathbf{P}_e$ = brine pressure leaving Turbo™

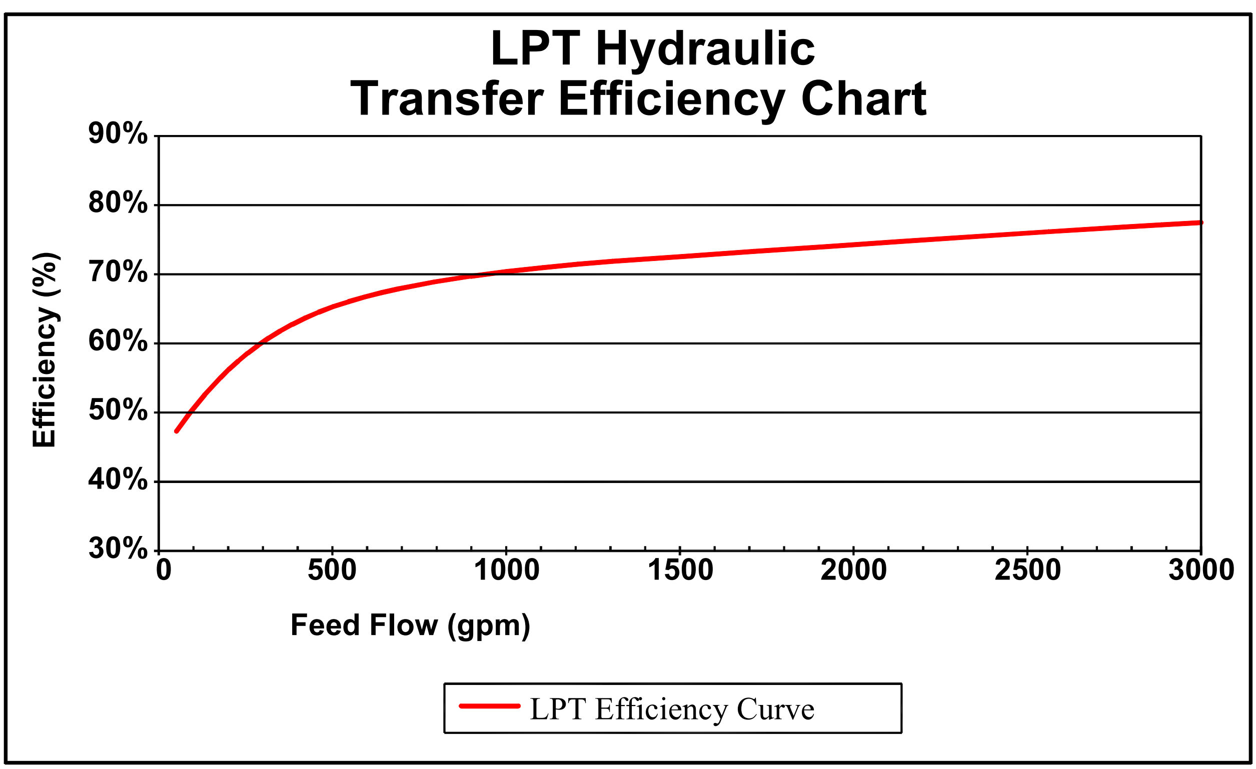
Example

A two stage BWRO system has an interstage flow of 500gpm, a second stage recovery of 50% and a second stage brine pressure of 175psi. To calculate the interstage Turbo boost pressure:

Determine hte from the LPT Turbo Transfer Efficiency Graph. At 500gpm, nte is approximately 63%.

Next substitute the numerical values in the equation:

$$\mathbf{DP}_{tc} = \mathbf{(.63)\,(.50)\,(175psi - 0) = 55\ psi}$$



A comparison of total Life Cycle Cost (LCC)

for a BWRO system with a motor driven booster pump and an LPT TurboCharger

"The total cost of a pump over its life cycle (Life Cycle Cost, LCC) will increasingly govern capital expenditures decisions of industrial users."

The above quote is from an article entitled "Life – cycle strategy for pumps improve cost structure" that appeared in the February 2001 issue of *World Pump* magazine. Over the past two years, *World Pump* has published six other major articles on the subject of LCC and how it is becoming a standard for evaluating pump purchase decisions for industrial users.

Life Cycle Cost is near self explanatory, however its actual formulation is given by the following Hydraulic Institute and Europump approved equation: **LCC = (Cic + Cin + Ce + Co + Cm + Cs + Cd)**

Where:
- **Cic** = intial cost, purchase price (pump, motor, controls)
- **Cin** = installation and commission
- **Ce** = energy cost
- **Co** = operating cost (labor cost of normal system supervision)
- **Cm** = maintenance cost (labor and parts)
- **Cs** = down time (cost of lost production)
- **Cenv** = environmental cost
- **Cd** = decommissioning cost

Interstage Booster Service

Specifically in the case of comparing a motor driven pump to a LPT Turbocharger in interstage booster service for a mulitstage brackish water or ultra pure water reverse osmosis system, the following are the major cost factors, while the remaining factors of the LCC formula are essentially equal.

The example below is for an LPT 250 to be used in a high purity two stage RO system. First stage feed pressure is 268 psi. The LPT Turbo will provide a boost of 76 psi with an interstage flow of 221 gpm.

Capacity (gpm) 221gpm
Head (ft) 154ft
Suction Pressure (psi) 232psi
Hours of Annual operation 8,500
Estimated cost of repair $750

Pump efficiency @ Duty Point .55
Motor power @ Duty Point (kW) 13.1kW
Installed motor size 20hp
Equipment life (years) 15
**Note: 3% annual inflation rate for cost of electrical energy.*

MAJOR COST FACTORS

	Motor Driven Pump	LPT 250
Cic (Initial Cost)		
Pump	$6,000	$10,000
Motor	$921	$0
Controller/VFD	$1,950	$0
Brine Control valve	$3,000	$0
Total Cic	$11,871	$10,000
Cin (Installation Cost)		
Electrical	$1,500	$0
Total Cin	$1,500	$0
Ce (Energy Cost)		
Annual Energy Use	110,602 kWh	0 kWh
Operating Life	15 years	15 years
Total Energy Use	1,659,180kWh	0 kWh
Electric Cost *($/kWh)	($.10)	
Total Ce	$205,700	$0

	Motor Driven Pump	LPT 250
Cm (Maintenance Cost)		
Average MTBF in months (mean time between failure)	36	180
Total number of repairs	5	0
Average repair cost	$750	$0
Total Cm	$3,750	$0
Cs (Loss of Production Cost)		
Shut downs for repairs	5	0
Loss factor cost is site specific		

Life Cycle Savings

Cic $1,187 advantage LPT
Cin $1,500 advantage LPT
Ce $205,700 advantage LPT
Cm $3,750 advantage LPT
Cs indeterminate
Total $212,137 advantage LPT!

The above comparison indicates conclusively, that energy cost is the single biggest component of Life Cycle Cost. This is so much so that even if the motor driven pump and all its associated equipment were free, its LCC would be reduced by only 6.5%. Please note that although we did not quantify downtime due to motor/pump failure, this is also a major Turbo advantage in that no low pressure Turbo has ever failed or even required maintenance since its introduction in this service over 10 years ago.

Through the use of custom machine 3D geometry impellers, PEI's new LPT shows substantial efficiency improvement (on average 15 – 20% higher) over the previous generation Turbo.

Multi Stage RO Design with the LPT

Design Technique

The method of calculating interstage LPT boost pressure and the application of the boost pressure to a multi-stage RO design will be illustrated by the following example. The example will be a two stage BWRO system that will produce 1000gpm of permeate at 75% recovery at a bulk feed TDS of 2750. For sake of brevity and clarity temperature changes will be minimal with no impact on design. In an actual system the LPT is able to handle significant changes in pressure through the use of its auxiliary nozzle and control valve, more of which is described in the LPT/RO System Control Section of this manual on page 13.

Using the membrane manufacture membrane performance projection software, run a baseline case (1) that employees neither permeate throttling or interstage pressure boosting. (See adjacent page for the result of case 1). Next run a case 2 for permeate throttling to achieve substantial flux balancing. (See adjacent page for case 2 results). Next run a case 3 for interstage pressure boosting. Use as a first trial interstage pressure, the same pressure that was used for permeate throttling. In our example this was 64 psi. The results from case 3 are displayed on the adjacent page.

Next we have to determine the value of the LPT boost pressure used in case 3. Use the Turbo boost formula found on page 8 in the “Turbo Performance” section.

For this example the boost pressure is:

Pboost = Pbrine (207 psi) x hte (.63) x Rr (.514) = 67 psi.
(Pbrine and Rr are given from the membrane projection, while hte is given from the graph in “Turbo Performance” section.)

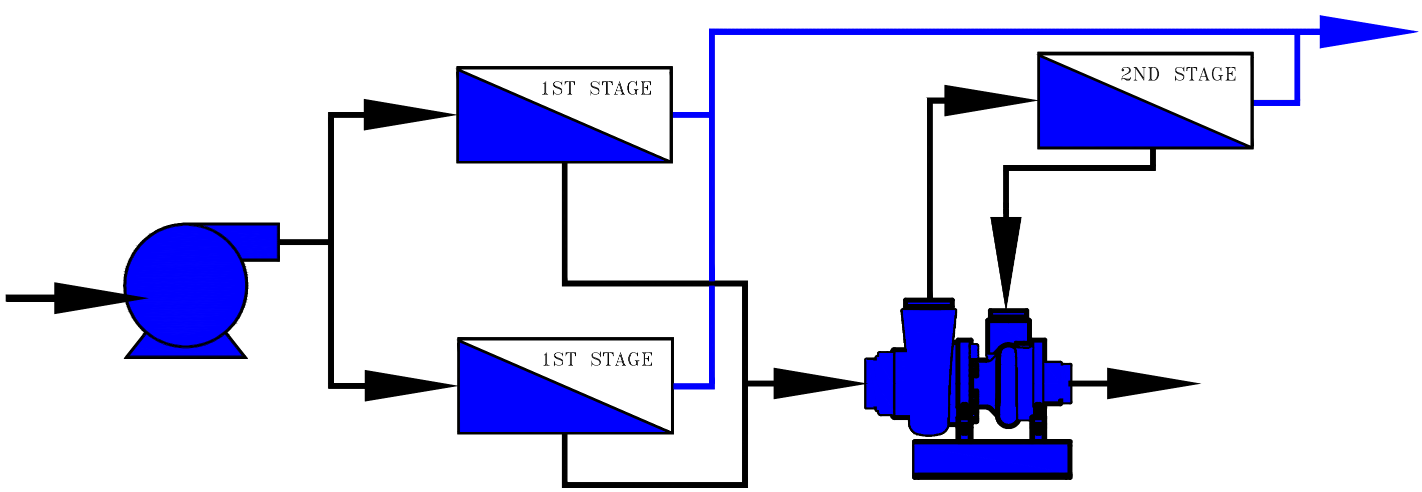
The result of 67 psi is sufficient for this application, however if this were a smaller system and LPT nte was lower, then the boost pressure would have been also lower. In such a case the membrane design would be adjusted so that the required boost pressure match the available boost pressure. Similarly, a larger, hence more efficient LPT would provide more than the required pressure with the given membrane design in our example and so again the membrane design could be reconfigured this time with fewer pressure vessels and membrane elements.

As case three indicates, membrane performance is maintained as in Case 2. However, first stage feed pressure has been reduced from 260 psi to 196 psi - a 25% reduction.

A Useful Formula

The following formula will provide a close approximation of the 2nd stage pressure when the 1st stage concentrate pressure and flow is known.

Pm2 = (Pr1 – hte Rr Pd2) / (1 – hte Rr)
Where Pm2 = second stage feed pressure
Pr1 = 1st stage concentrate pressure
Pd2 = pressure drop through 2nd stage membranes
hte = LPT hydraulic transfer efficiency
Rr = 2nd stage reject ratio



Case 1

Feed Flow to Stage 1	1333.00 gpm	**Permeate Flow**	999.74 gpm
Raw Water Flow to System	1333.00 gpm	**Recovery**	75.00 %
Feed Pressure	225.86 psig	**Feed Temperature**	25.00 C
Fouling Factor	0.85	**Feed TDS**	2750.00 mg/l
Chem. Dose (100% H2SO4)	0.00 mg/l	**Number of Elements**	234
Total Active Area	93600.00 ft2	**Average System Flux**	15.38 gfd
Water Classification	Surface Supply SDI < 3		

Stage	Element	#PV	#Ele	Feed Flow (gpm)	Feed Press (psig)	Recirc Flow (gpm)	Conc Flow (gpm)	Conc Press (psig)	Perm Flow (gpm)	Avg Flux (gfd)	Perm Press (psig)	Boost Press (psig)	Perm TDS (mg/l)
1		26	6	1333.00	220.86	0.00	540.33	198.53	792.67	18.29	0.00	0.00	24.50
2		13	6	540.33	193.53	0.00	333.26	173.54	207.08	9.56	0.00	0.00	85.11

Case 2

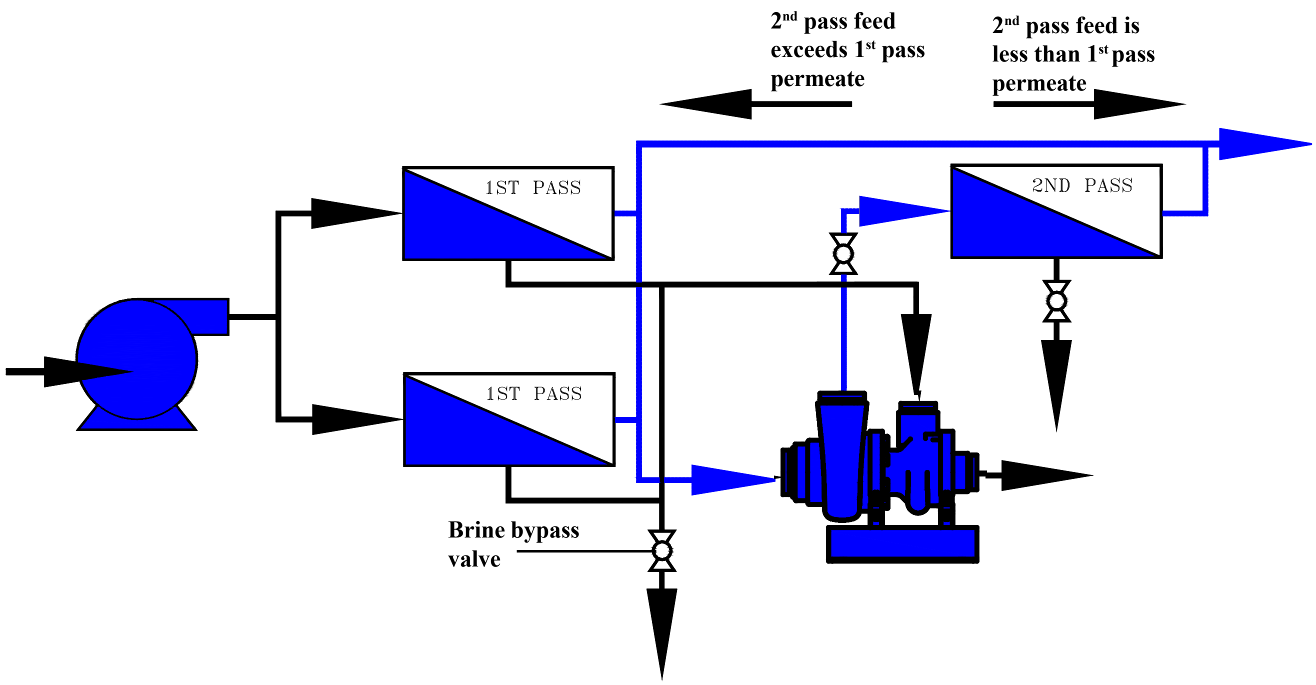
Feed Flow to Stage 1	1333.00 gpm	**Permeate Flow**	999.74 gpm
Raw Water Flow to System	1333.00 gpm	**Recovery**	75.00 %
Feed Pressure	265.00 psig	**Feed Temperature**	25.00 C
Fouling Factor	0.85	**Feed TDS**	2750.00 mg/l
Chem. Dose (100% H2SO4)	0.00	**Number of Elements**	234
Total Active Area	93600.00 ft2	**Average System Flux**	15.38 gfd
Water Classification	Surface Supply SDI < 3		

Stage	Element	#PV	#Ele	Feed Flow (gpm)	Feed Press (psig)	Recirc Flow (gpm)	Conc Flow (gpm)	Conc Press (psig)	Perm Flow (gpm)	Avg Flux (gfd)	Perm Press (psig)	Boost Press (psig)	Perm TDS (mg/l)
1		26	6	1333.00	260.00	0.00	647.53	235.79	685.47	15.82	64.00	0.00	25.27
2		13	6	647.53	230.79	0.00	333.26	207.26	314.28	14.51	0.00	0.00	54.61

Case 3

Feed Flow to Stage 1	1333.00 gpm	**Permeate Flow**	999.74 gpm
Raw Water Flow to System	1333.00 gpm	**Recovery**	75.00 %
Feed Pressure	201.00 psig	**Feed Temperature**	25.00 C
Fouling Factor	0.85	**Feed TDS**	2750.00 mg/l
Chem. Dose (100% H2SO4)	0.00	**Number of Elements**	234
Total Active Area	93600.00 ft2	**Average System Flux**	15.38 gfd
Water Classification	Surface Supply SDI < 3		

Stage	Element	#PV	#Ele	Feed Flow (gpm)	Feed Press (psig)	Recirc Flow (gpm)	Conc Flow (gpm)	Conc Press (psig)	Perm Flow (gpm)	Avg Flux (gfd)	Perm Press (psig)	Boost Press (psig)	Perm TDS (mg/l)
1		26	6	1333.00	196.00	0.00	647.54	171.79	685.46	15.82	0.00	0.00	25.27
2		13	6	647.54	230.79	0.00	333.26	207.26	314.28	14.51	0.00	64.00	54.61



TURBO™ as a Second Pass Feed Pump

Sometimes, RO plants cannot produce the desired permeate TDS with one membrane pass. In such cases, the permeate is further processed in a separate RO system called the "second pass".

The second pass RO system usually requires an electrically driven feed pump to pressurize the first pass permeate before introduction to the second pass membranes.

The first pass membranes can be either brackish or seawater; the second pass modules are almost always low pressure units. The Turbo™ offers the unique opportunity to combine second pass pressurization with first pass energy recovery.

As illustrated above, the Turbo™ is energized by high pressure brine from the first pass. The Turbo™ boosts the pressure of the permeate from the first pass to the level required for the second pass membranes. Since the Turbo™ usually uses only a fraction of the first pass brine, a brine bypass valve is included to dispose of the excess high pressure brine.

Simplified Piping

Many systems using a second pass include a first pass permeate storage tank. The tank also includes a level sensor and electrical relay to stabilize feed flow to the second pass system and to accuate the second pass system when the tank level reaches a predetermined point.

Figure 20 illustrates a piping arrangement that eliminates the need for a first pass permeate storage tank and associated controls.

Note that if the second pass draws more permeate than the first pass produces then some of the second pass permeate will recirculate through the second pass membrane (indicated by the arrow pointing left in Figure 20).

If the first pass permeate flow exceeds the feed flow to the 2nd pass then some first pass permeate will bypass the 2nd pass (indicated by the arrow pointing to the right) and will blend with the second pass permeate.

Flexible Operation

Note that if an especially low TDS in the second pass permeate is desired, the second pass feed flow can be increased by adjustment of the brine bypass valve to deliberately recirculate some of the 2nd pass permeate (i.e. achieve a flow direction indicated by the arrow point left).

Conversely, if the combined TDS is too low, the feed to the second pass can be reduced resulting in a portion of the first pass permeate bypassing the second pass.

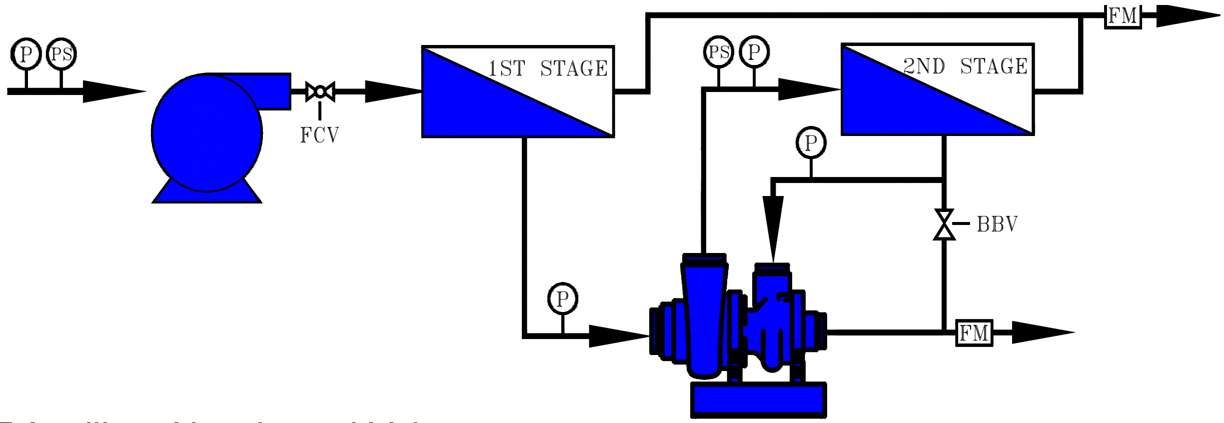
Note that the second pass can only operate when the first pass is operating and providing the Turbo™ with high pressure brine.

Benefits of the Turbo™

- Reduced energy consumption.
- Elimination of all capital and electrical equipment for 2nd pass pump.
- Variable pressure boost and flow to meet new conditions.
- Zero-maintenance.

Contact PEI for a capital cost comparison.

Piping, Valving, Instrumentation and Control



LPT Auxiliary Nozzle and Valve

All LPT are equipped with main nozzle that is located in the turbine inlet pipe. This nozzle is sized to produce a pressure resistance that is equal to the maximum anticipated membrane plus a 5% operational margin. In addition to the main nozzle there is a smaller secondary nozzle whose area is 25% of the main nozzle. This Auxiliary Nozzle (AN - see figure below) is located 90^0 from the main nozzle and is controlled by the Auxiliary Nozzle Valve (ANV). During those periods of RO plant operation that required less pressure then maximum membrane pressure, the ANV is open to create a parallel flow both with the main nozzle. This increases the total nozzle area, allowing more flow and/or a lower pressure. Typically, the Auxiliary Nozzle can reduce concentrate pressure and a constant flow rate by 20 – 25%. The ANV can be either a manually or power actuated valve.

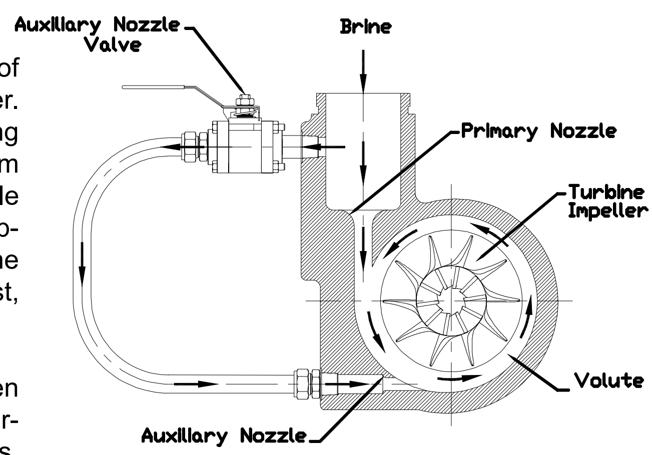
BWRO systems typically utilize centrifugal pumps as the high pressure feed pump. Referring to the figure above, a basic two stage RO system equipped with an LPT Turbocharger is illustrated. The pressure indicators, pressure switches, and flow meters are recommended for proper monitoring and control of a Turbo equipped RO plant. A Flow Control Valve (FCV) is positioned between the pump discharge and the 1st stage membrane block. This valve is used in conjunction with the LPT's auxiliary nozzle valve to control brine flow and membrane pressure. Another valve is an optional Brine Bypass Valve (BBV).

The Flow Control Valve (FCV) has a number of purposes:

- The FCV can be set in a partially closed position to reduce pump capacity, hence lower pump motor starting amperage and power
- The FCV is used in conjunction with the LPT Auxiliary Nozzle Valve (ANV) to control membrane flow and pressure. If membrane pressure requirements are reduced, then the LPT's ANV is opened to reduce system resistance (pressure). At the same time the FCV is closed to maintain constant flow at the reduced pressure. To increase membrane pressure the opposite valve movements are made. The ANV will be closed and the FCV will be opened.

If the RO system high pressure pump motor is equipped with a Variable Frequency Drive (VFD) then membrane pressure can be controlled by adjusting motor speed. This would eliminate the need for the Flow Control Valve. The VFD option with no FCV is very well suited when pressure downturns are in the range of 25- 50% or less. However, if a greater pressure downturn range is required, a pump speed change necessary to meet the new lower pressure requirement may reduce membrane flow to an unacceptable level, so here again a FCV should be included in the design.

The same factors affecting the use the pressure/flow range of a VFD driven pump also affect the LPT in a similar manner. The LPT's ANV can change its system resistance (operating pressure) sufficient for a 20 – 25% range. If the RO system needs to operate over a wider pressure range (for example 150 – 300psi), then a Brine Bypass Valve (BBV) can be supplied with the LPT. The BBV will directly route a portion of the brine flow from turbine inlet directly to the turbine exhaust, thereby bypassing the Turbo internal flow path completely.



Note: There are maximum allowable bypass quantities when utilizing the BBV. Due to custom engineering and manufacturing of each unit, please contact PEI for your specific limitations.

Installation

Characteristics of the LPT Turbo that effect its installation in typical multistage BWRO or ultrapure water RO plant are as follows:

Compact Size and Weight

Because of its high speed operation, an LPT Turbo is much smaller than an equivalent capacity motor driven pump, as much as five to tens times smaller. For instance a 100gpm Turbo weighs 40lbs vs 400lbs or more for a motor driven high pressure pump. This factor makes it ideal for skid mounted or containerized system, where space restrictions are always an important consideration.

Flexible Installation Location

The Turbo is mountable in any orientation. The standard base is a saddle type that allows the turbine casing to be rotated 360 degrees. The pump casing can also be rotated in relation to the turbine casing in 45 degree increments.

Piping and Foundations

Victaulic pipe connections are standard on LPT Turbos from model LPT 63 through model LPT 2000 Because of their relatively small size and vibration free operation foundation requirements are very modest and are primarily designed to support piping loads that the Turbo may be carrying.

Low Noise and Pulsation Free Flow

Highly efficient hydraulic design of the LPT Turbo significantly minimizes noise generation to such an extant that is not audible over the background noise of a typical RO plant. In addition, because the Turbo downsizes the high pressure pump and motor size and pressure requirements, there is a noise reduction associated with this equipment. The high speed centrifugal principle of Turbo operation assures pulsation free smooth flow to the membranes.

Pressurized Brine Discharge

The LPT Turbo can discharge brine (concentrate) against practically any level of backpressure. So there is never any need for brine disposal pumps or gravity flow piping or trenches.

LPT Turbo Recommended Requirements

- Pressure gauges or transducers should be installed near each Turbo pipe connection to permit monitoring of Turbo performance.
- Perform all pipe clean and flushing before final installation and start up of the Turbo

Maintenance and Overhaul

The LPT Turbo has no scheduled maintenance requirements. There are no shaft couplings to align, no shaft seals (leading cause of pump failure), no lubrication system or lubricants (second leading cause of pump failure), and no external auxiliary services such as cooling water or pneumatic requirements.

See the Installation and Operation Manual for complete information.

Overhaul and Repair

Because of its relative small size and single stage design, even the largest Turbo can be completely inspected and/or overhauled in a few hours. All bearings are slip fit and O ring mounted, making their removal and installation a quick, simple, and straightforward job. PEI stocks all parts necessary for any repairs that may occur.