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White Paper

A Comparison of Energy Recovery Devices: Hydraulic Pressure Booster and the Pelton Impulse Turbine

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Executive Summary

- Energy savings from 6% to 20%
- Total cost typically 50% less than the cost of the PIT system
- Much more compact and lower weight, easier to install
- More reliable and easier to maintain

Introduction

This paper compares the cost factors of the Hydraulic Pressure Booster (HPB) energy recovery device manufactured by Fluid Equipment Development Company (FEDCO) with the Pelton Impulse Turbine (PIT) in seawater reverse osmosis (SWRO) applications. All assumptions are based on reasonable engineering estimates.

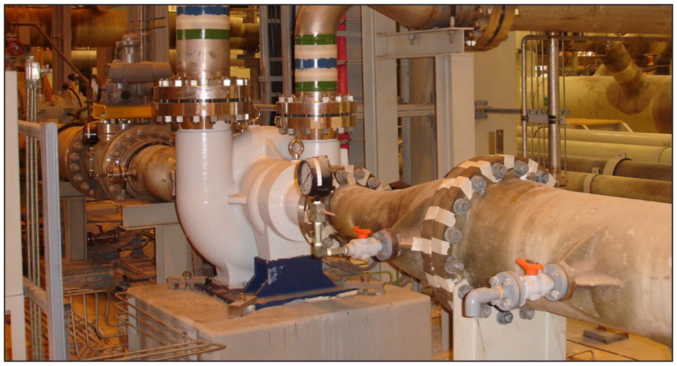
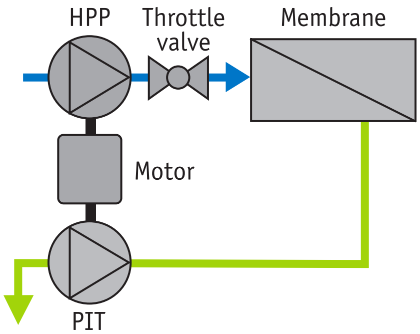


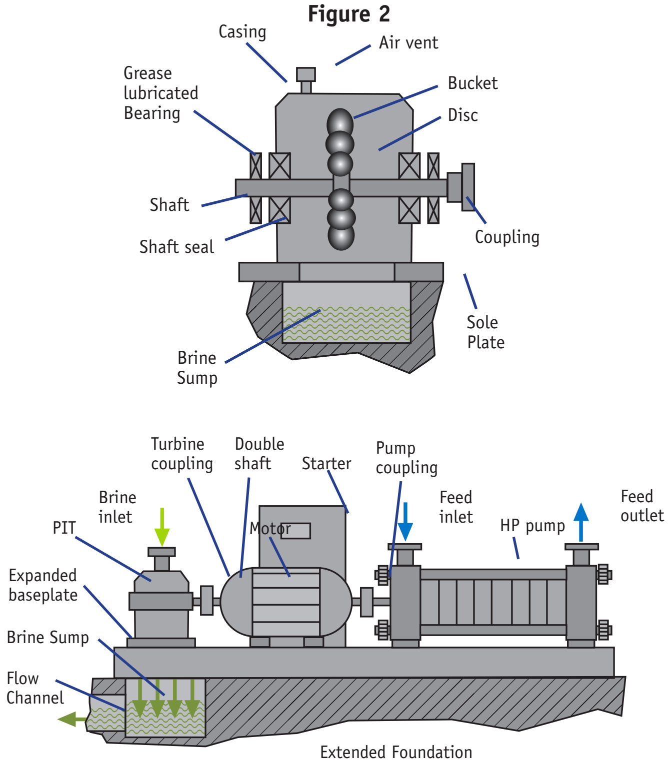
Figure 1



Pelton Impulse Turbine

The Pelton Impulse Turbine (PIT) converts hydraulic energy in the brine stream into mechanical power, which is transmitted to the high pressure (HP) pump through the HP pump motor shaft. A throttle valve is typically used to regulate membrane pressure. Refer to Figure 1.

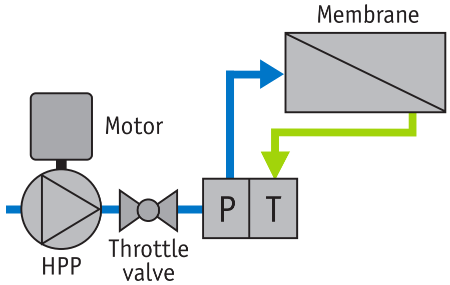
Figure 2



The PIT employs a turbine runner operating in an air-filled casing. One or two nozzles direct high velocity jets of brine at specially shaped buckets mounted on the periphery of a rotatable disc. These buckets catch and redirect the high velocity brine jets thereby imparting torque on the disc and attached shaft. Brine flow and pressure can be controlled by use of a variable area nozzle.

The shaft is supported at each end by oil or grease lubricated bearings. The casing supports the bearings and includes an air vent to equalize internal pressure with ambient atmospheric pressure. Since the casing is

Figure 3



at atmospheric pressure, the PIT must discharge into an open sump.

The PIT shaft usually connects to a shaft extension from the HP pump motor. Numerous modifications are required to the feed pump, motor, baseplate, foundation and brine disposal system to accommodate the PIT as indicated in Figure 2.

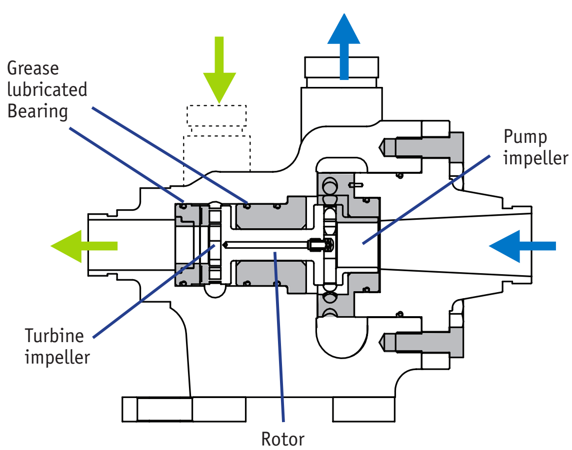
Hydraulic Pressure Booster

The Hydraulic Pressure Booster (HPB) uses high pressure brine energy to boost the pressure in the feed stream. The HPB pressure boost reduces the discharge pressure requirement of the HP pump by up to 45% thereby saving energy and reducing the size of the HP pump and motor. Please refer to Figure 3.

The HPB rotor is free to rotate at any speed necessary to accommodate variable flows and pressures. Bearings are lubricated by feed water. The HPB rotor is entirely contained with the casing, thus, there are no shaft seals and no potential for leakage. Please refer to Figure 4.

The HPB uses an adjustable brine nozzle to regulate brine flow and pressure. The valve may be controlled manually or with an actuator.

Figure 4



The HPB may be installed anywhere in the RO system such as on the membrane skid. The HPB may be used with any type of feed pump including vertical, horizontal, positive displacement pumps of all types, etc.

Transfer Efficiency

Transfer efficiency is defined as the ratio of hydraulic power transferred to the feed stream divided by the hydraulic power available in the brine stream.

The PIT converts brine energy into shaft power that is converted to hydraulic energy by the feed pump. The transfer efficiency, Nte, for the PIT and HP pump is:

Nte = Nteff x Npeff

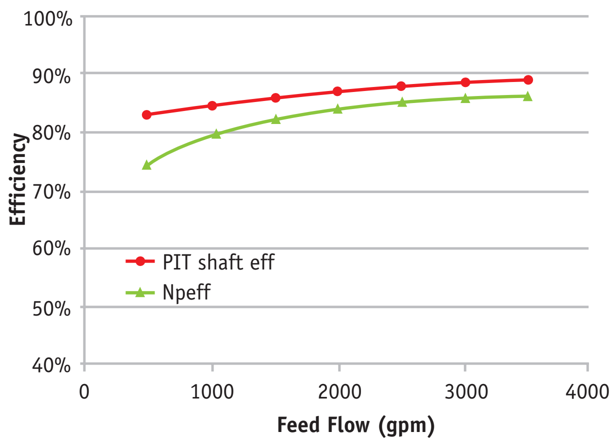
where

Nteff = Turbine efficiency

Npeff = Pump efficiency

Figure 5

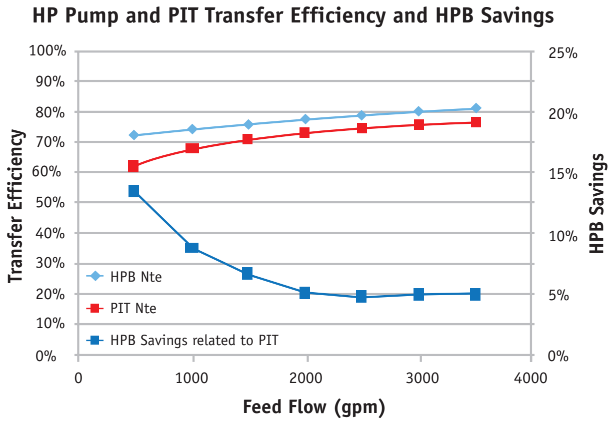
HP Pump and PIT Efficiencies



For example, a PIT with an 87% turbine efficiency connected to a feed pump with an efficiency of 78% has a transfer efficiency of 67.9% (0.87 x 0.78 = 0.679). Note that HPB transfer efficiency is independent of HP pump efficiency.

Figure 5 shows typical HP pump and PIT efficiencies as a function of feed flow (PIT flow equals 60% of feed flow). Data is from various published sources. Figure 6 indicates the HPB savings over the PIT ranges from 5% to 14% based HP pump efficiency in Figure 5.

Figure 6



Installation Comparison

The HPB eliminates of mechanical linkage with the HP pump and motor as well as reduction of the HP pump, motor, baseplate and associated motor starter and switchgear. This means that the HPB:

HPB	PIT
• Can discharge brine above atmospheric pressure for easy disposal through PVC or GRP piping	• Must discharge in gravity spill ways
• Can be mounted in any orientation including vertically to simplify pipe layouts and fabrication	• Restricted location, must be precisely aligned with the HP pump motor on a special baseplate
• Can be mounted anywhere in the system skid for reduced piping costs	• No freedom of location
• Brine stream is fully enclosed and may be pressurized for long distance disposal	• Can release noxious gases (H_2S) to the atmosphere • Can be subject to severe foaming of the brine • Requires large sump under baseplate
• Compact installation	• Requires much large footprint • Of great weight, requires suitable foundation

Capital Cost Comparison

The HPB accomplishes both energy recovery and feed pumping resulting in a significant reduction in the size of the HP pump and motor. The HPB and the PIT have approximately equal in purchase prices. However, the HPB provides a significant cost reduction in HP pump and motor costs as well in general installation costs including:

HPB reduces the HP pump discharge requirement by approximately 30% to 55%	• Fewer pumping stages • Smaller baseplate • Smaller motor, motor starter • Smaller switch gear and power supply
HPB reduces infrastructure costs procedures	• Smaller and less massive foundations • Smaller lifting equipment • Less floor space
HPB simplifies brine disposal system	• Eliminates large gravity flow brine channels • Discharge brine at any pressure to eliminates need for brine re-pressurization • Contains noxious gases such as hydrogen sulfide

Reliability Comparison

Lubrication Requirements	The PIT's rolling contact bearings require grease or oil lubrication. They are subject to failure modes including lack of lubrication, contamination by brine, dust and grit as well as by high ambient temperature and humidity. Note that HPB bearings are isolated from all ambient environmental factors.
Overhaul Requirements	A PIT may take several days to overhaul and re-align by skilled labor. An HPB overhaul takes from 15 to 60 minutes. Skilled labor and special tools are not required.
Consequence of Equipment Failure	PIT failures can destroy the HP motor and HP pump resulting in weeks of downtime and major expenses. A worst-case failure of the HPB is confined to the unit itself.
Nozzle and Rotor Erosion Potential	The PIT generates the entire pressure drop in the nozzle resulting in a very high velocity brine jet maximizing the potential for erosion. In the HPB, the flow velocities are much lower resulting in negligible erosions potential.

Operational Analysis – Feed Throttle Valve Pressure Control

For each type of ERD, the HP pump power consumption remains constant as feed flow and pump RPM are constant. The PIT power output falls in response to feed throttling because the brine pressure to the PIT is reduced by an amount equal to the throttle loss. Therefore, **the HP pump motor output must increase to accommodate the decreased PIT power contribution.** Figure 6 shows the increasing HP pump motor output in response to feed throttling. Figure 6 data is derived from Figure 5 data at a feed flow of 2,000 gpm.

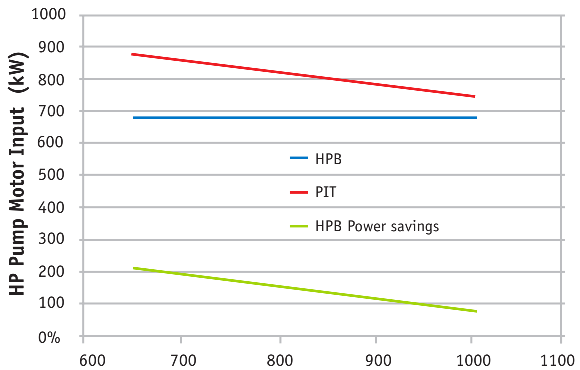
The situation is different for the HPB. Feed throttling has no effect on the HP pump motor power output. Thus energy consumption remains constant regardless of the amount of throttling as illustrated in Figure 8.

The HPB energy reduction over the PIT ranges from 67 kW (9% savings) with zero feed throttling (1,000 psig membrane pressure) to 169 kW (20% savings) at 250 psi throttling (750 psig membrane pressure).

Feed throttling significantly enhances the energy efficiency advantage of the HPB relative to the PIT.

Figure 8

Effects of Throttling on Power Consumption



Conclusion

From the forgoing, the HPB represents a significant improvement over the PIT in energy savings, capital cost, reliability and maintenance. The following highlights the specific advantages of the HPB relative to the PIT.

1. Significantly lower capital cost,
2. Lower energy consumption,
3. Additional energy savings if feed throttling is used;
4. Significantly reduced size and cost of the high pressure pump, motor and switchgear,
5. Less expensive brine disposal system,
6. No potential for brine foaming or release of odor to the atmosphere,
7. an be overhauled more quickly and at a lower cost,
8. A failure, the HPB will not damage the HP feed pump and motor,
9. The HPB and HP pump package weighs less and has a smaller footprint.