PEI Technical Note Book

Pump Engineering, Inc. **Issue 3** *April 1999*

How Changes in System Pressure Effects ERT Efficiency: a Comparison of the Turbo™, the PIT and RRPT

In Issue No. 1 of the PEI Technical Note Book we examined how feed stream throttling decreased the brine energy available to the ERT and how that reduction affected the power recovery of the ERT and the power consumption of the high pressure pump's motor. In Issue No. 2 we established the definition of hydraulic transfer efficiency as the measure of true ERT efficiency. In this issue we will examine another facet of ERT efficiency and that is how the mechanical efficiency of the ERT changes at off design conditions. The Turbo™, Pelton Impulse Turbine (PIT) and Reverse Running Pump Turbine (RRPT) will again be examined for the real world conditions that energy recovery turbines encounter more often than not in reverse osmosis service.

In Issue 1, our comparison of the Turbo™ and the PIT assumed for the sake of clarity (by looking at only the one parameter of pressure) that mechanical efficiency remained constant with varying operating pressure. This unfortunately is not the actual case. All turbo machines operating with fixed flow geometry (usually the case for RO ERT) at fixed speeds will display considerable reductions in efficiency when operated at off design conditions. For instance a PIT will have zero efficiency when the pressure ahead of the needle control valve is at about 40% of design pressure. Similarly a RRPT will not produce power below 40% of design flow rates, and it will actually consume power. The Turbo™ on the other hand will show little difference in efficiency between 40% flow and pressure and 100% flow and pressure. What's the difference? The difference is the Turbo™ is a variable speed machine and inherently adjusts its speed of operation to meet the conditions of operation. The pump side of the turbo which produces the boost pressure is driven by a hydraulic turbine mounted on the same shaft, both of which respond similarly to changes in operating conditions. The ability to change rotor speed allows the impellers to minimize the mismatch of off design flow angles that otherwise occur with fixed speed machines.

Figures 1, 2 and 3 illustrate efficiency change Vs. flow and pressure for the Turbo™, PIT, and the RRPT.

**For a detailed definition of mechanical and hydraulic transfer efficiency see Tech Note Book Issue 1.*

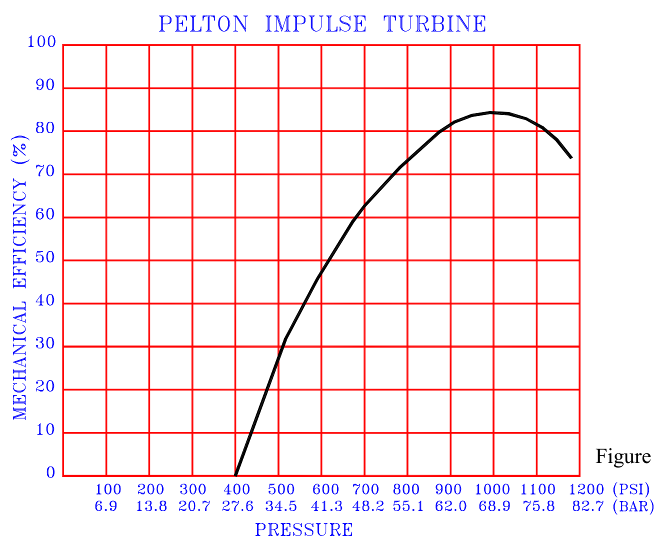

Figure 1

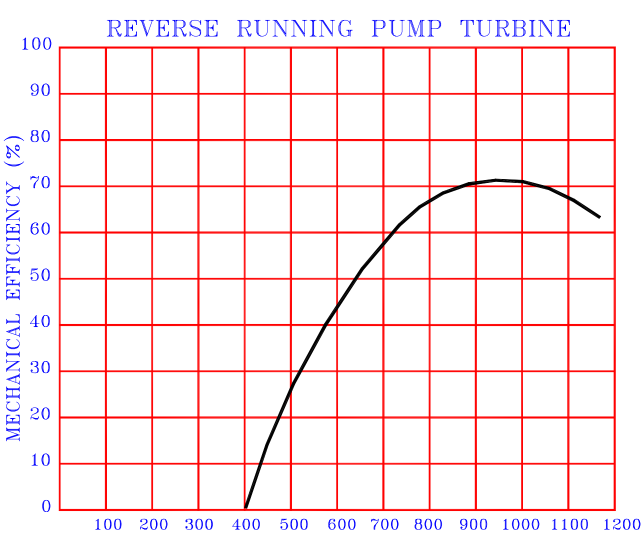

Figure 2

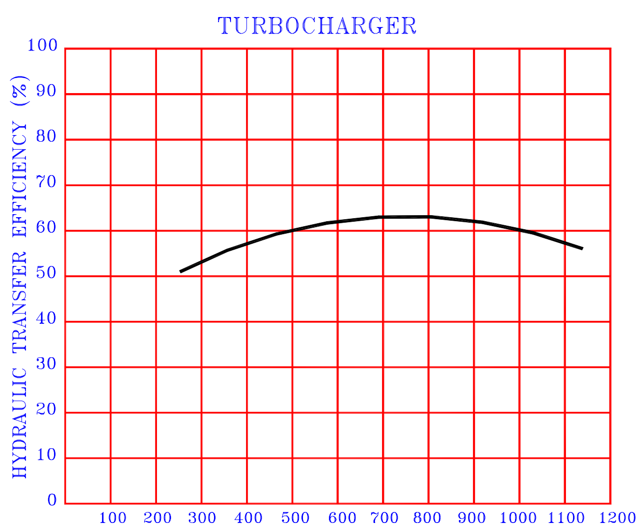

Figure 3

The graphs of the PIT show that no power is produced when operating pressure falls below approximately 400 psi or 40% of design (best efficiency point-BEP) pressure. A PIT converts pressure energy into a high velocity jet whose velocity is equal to $V = k\ (h/2g)^{(1/2)}$. The kinetic energy of the jet stream is transferred to the buckets of the impulse turbine where maximum efficiency is achieved when the wheel velocity at radius of jet action is equal to .46 of the jet velocity. When a PIT is sized and selected for an application the working radius of the buckets and the rpm of the shaft are matched as closely as possible to the design head of the system in order to achieve the .46 jet velocity to bucket velocity ratio. If for any reason the actual operating pressure is different than the design pressure then the jet velocity/wheel velocity ratio becomes increasing mismatched. If operating pressure were to decline to a point where the jet velocity was just sufficiently greater than wheel velocity to provide only enough power to overcome bearing, seal and windage losses then the net power output would be zero.

PEI experience in the sea water reverse osmosis industry includes many examples of systems using wells as the feed source in which the actual well TDS was different enough from the design TDS to cause a 300 to 400 psi change in operating pressure as compared to the design pressure. As an example, in Issue 1 we compared the power consumptions of the high pressure pump at different membrane pressurres achieved through throttling. If we included the efficiency correction factor to our design case of Issue 1 the new corrected for off design efficiency change results would be as shown in Figure 4.

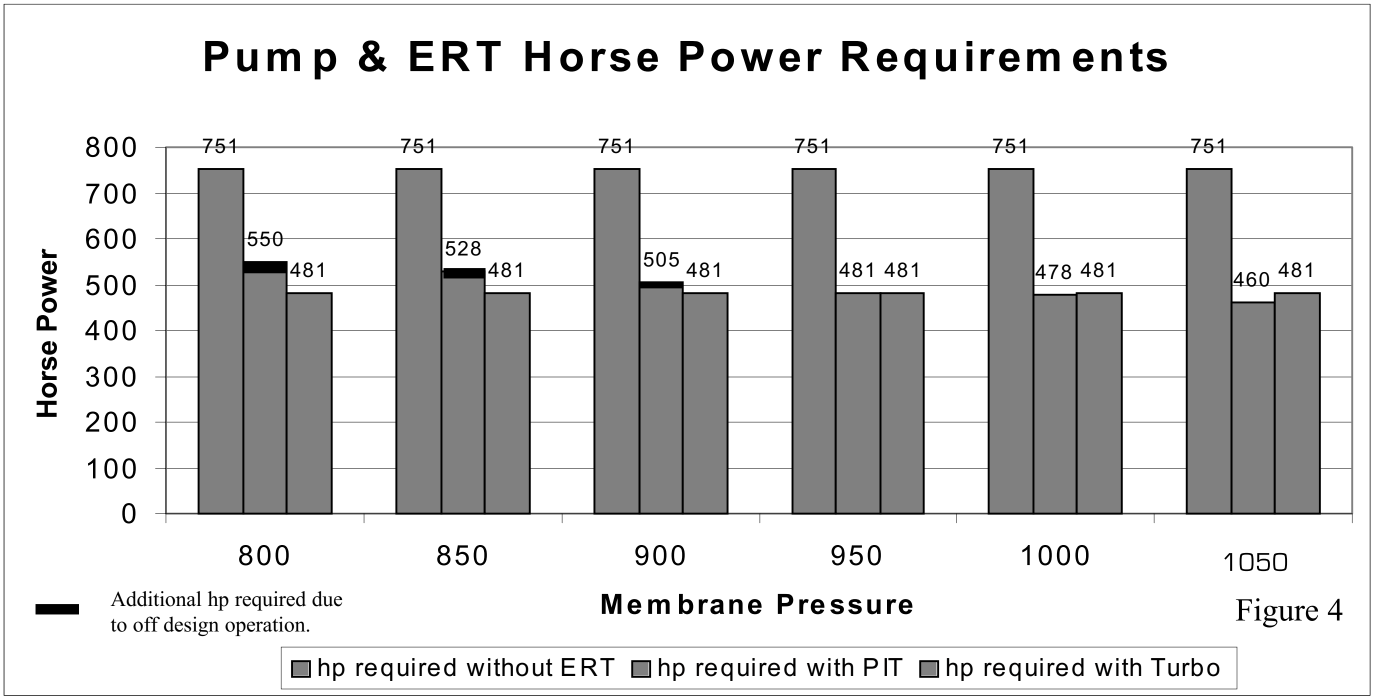

Figure 4

Again referring to Figure 3 we see the Turbo™ efficiency is virtually unchanged. Actually real Turbo™ efficiency will increase 2 to 3 points because the lower pressure operation has the effect of increasing the specific speed of the impellers which makes them more efficient.

The RRPT like the PIT suffers greatly from reduced pressure operation. RRPT installation requires a valve arrangement for off design condition so that brine flow can be either throttled to or bypassed around the RRPT. For our example a RRPT designed to operate with 600 gpm @ 980 psi brine pressure drop at BEP would have to bypass approximately 10% of the brine flow at 800 psi. Taking a typical RRPT efficiency of 72% at BEP and correcting it to 65% for 800 psi operation and factoring in the loss from bypassing 10% of brine flow, the true mechanical efficiency is now 58% and the hydraulic transfer efficiency (Nhte) is 44%. The Turbo™ under the same condition would show an increase of Nhtc from 60% to 62%, a full 41% higher than the RRPT.

The above design examples are not the exception in seawater RO desalination. PEI unit operation history indicates that a majority of installations operate 10% or more from design pressure and an unexpectedly high number are out there at 40 to 50% of design. The real world of RO operation is rarely described by one set of parameters. However, there is one ERT that can effectively and efficiently deal with the constantly changing conditions of reverse osmosis desalination, the TURBO by Pump Engineering, Inc.

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