Tech Talk

"Flow Economy" Determining True Pump System Efficiency

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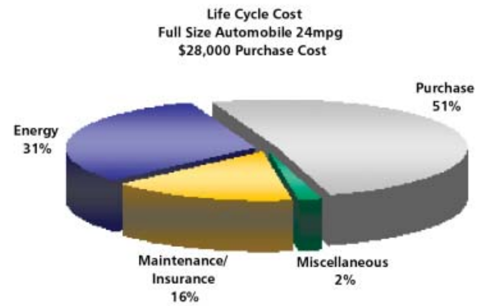
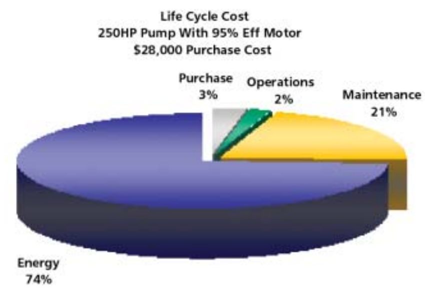
Imagine a source that accounts for nearly 20% of the world's energy demand yet has little regulation on how that energy is used. It is a surprising fact to many people that pumps consume so much of the world's energy, but if you were to think about everyday life in some fashion, a pump likely had a role in making it possible. From turning on the faucet in the morning, from the gas in your car, from the silicon chip in your cell phone to the shirt you are wearing. Consider that an average automobile consumes approximately 40,000 gallons of water to manufacturer. Pumps move every gallon. As populations and world economies grow, the demand for clean water, oil, bio-fuels, manufactured goods, and consumer goods will increase. And more and more pumps will be called on to help produce and deliver these goods.

A properly sized and operated pump can be one of the most efficient means of performing useful work. Consider that an average sized pump will operate near 75% efficiency. Compare that to a combustible engine which operates at only 20% efficiency. In relative terms a pump can be a very efficient piece of machinery. It is easy to lose sight of the enormous potential for energy savings that exists by optimizing pump systems. The problem is that a pump is very sensitive to how it is operated. And, it is the pumping system that has the greatest influence on pump energy use. For the most part, pumps are controlled in the same manner they where 50 years ago. New technologies have been slow to be adopted in industry. With the rising cost of energy, only recently has there been a renewed focus on reducing energy cost of pumps.

A simple way to put pumps in perspective is to compare a pump with an automobile. There are actually many parallels that both pumps and automobiles share. First look at the focus on fuel efficiency, alternative fuels and hybrid cars. There is a simple understanding of where the energy goes in a car, the gas tank. The problem with pumps is there seems to be a lack of knowledge of how pumps use energy and how much of the energy is performing useful work.

Consider the life cycle costs of both an automobile and pump with an initial purchase price of $28,000. When purchasing an automobile, fuel economy is a key factor in the decision-making process, and it is justifiable as it makes up nearly one-third of the cost of ownership. Energy can account for as much as 75% of the total cost of ownership of a pump, and here lies a tremendous potential. Market demand and government regulations are driving new technologies and innovation in the automobile industry, but this will





take years to produce results. On the other hand, the pump industry already has the technology in place to see immediate results by shifting the focus away from the pump and to the entire pump system.

Pumps are a $30 billion market. There is a multitude of organizations (i.e Hydraulic Institute, Europumps, etc.) that set forth guidelines for pumps but these are set in place from a manufacturing and mechanical design perspective. The operation of pumps and how the pumps consume energy is the ultimate responsibility of the pump system designer and the operator of that system.

The place to start is to understand what a pump does. A pump is a machine that converts mechanical energy into pressure energy. The pressure energy is imparted into a fluid which in turns creates flow by the movement of high pressure to low pressure. A pump is often evaluated on how efficiently it imparts a given pressure to a specific amount of fluid. At first the reaction to lowering pump energy consumption would be to mandate minimum pump efficiencies to the pump manufacturers.

The problem with this is that pump design and efficiencies have not changed much over the last 50 years. There have been some minor improvements in pump efficiency over the years with various coatings

Tech Talk

"Flow Economy" Continued...

technologies, smoother machined surfaces and computer-aided design, but this has really only provided small single digit gains. Barring any technological breakthrough in pump design, pump efficiencies are already maximized.

The bigger question is what does pump efficiency really determine about the pump system? Pump efficiency often is taken to even greater detail and evaluated using the wire-to-water efficiency which includes all losses such as the motor and pump losses. While this does provide a slightly more detailed picture, it gives little indication of how much useful work is being performed by the pump.

For example, an automobile is not evaluated by efficiency, it is evaluated by fuel economy. Fuel economy is a very useful metric because it defines how much useful work (miles) is generated per unit of energy (gallon of gasoline). If an automobile were evaluated by efficiency, then imagine operating an automobile at 55 mph all the time because that is the most efficient speed in which to operate the engine. To slow down, rather than release the accelerometer of the car, the brake is applied instead until the car slows down to the desired speed while still maintaining the most efficient motor rpm. While the engine may be operating at the most efficient rpm, the fuel economy of the car will be immediately impacted from wasted energy being dissipated by the automobiles brakes. This would obviously be a very inefficient manner to operate a vehicle and have a very negative impact on the fuel economy of the automobile.

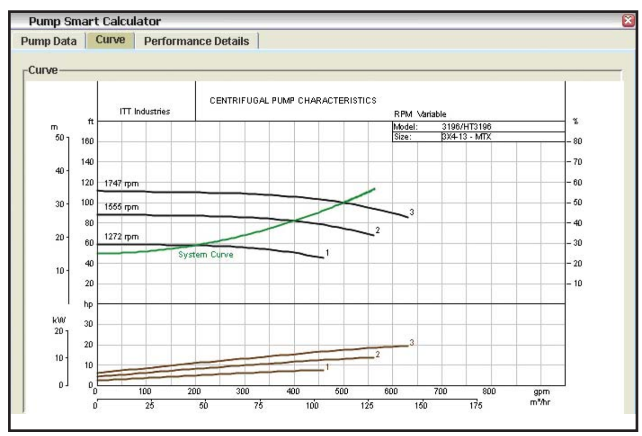
Yet the majority of pumps are operated in this very same manner. A typical pump runs at a fixed maximum speed with a valve throttled on the pump discharge to regulate the output of the pump. Even if the pump is throttled back to its most efficient point, it could actually be doing very little useful work as the majority of the energy is being dissipated into the pump system in the form of heat, noise, and vibration. One of the largest downfalls to pump operation is the lack of visibility into how much useful work the pump is actually performing. There are methods in the industry to evaluate pump efficiency, but as the automobile industry has shown, efficiency is not the important factor.

If we take the same logic as the automobile industry and apply it to pumps, you can now easily define how efficient the pump system is beyond the pump flanges. Similar to fuel economy for a pump system, a simple Flow Economy Ratio can be defined as pump flow / pump power. This ratio defines for every 1 kilowatt (kW) of work being performed the pump is able to move so many gallons per minute (gpm).

$$\text{FlowEconomy} = \frac{\text{flow}}{\text{power}} = \frac{\text{gpm}}{\text{kW}}$$

With this ratio it is now possible to evaluate the efficiency of the entire pump system. Not only is this metric useful in evaluating a pump system, but it can also quickly gauge if the pump system efficiency has changed. This provides the operator of a pump system the information required to quickly make decisions in the best interest of both the process and the pump.

In the following example both wire-to-water efficiency and flow economy are used to evaluate a simple pump system. The evaluation compares a fixed speed pump system using a control valve verses a variable speed pump system using a variable speed drive. The system is using a centrifugal pump with varying flow rates.



The following analysis was performed with the ITT PumpSmart Calculator Program.

Fixed Speed Pump with Control Valve

Flows	Time	Operating Hours	Flow (gpm)	Head (ft)	Speed (rpm)	Power (HP)	Pump Eff	Motor Eff	VSD Eff	Wire to Water Eff	Total Power (KW)	Flow Economy (gpm/kW)	kW hrs
Qmin	30%	2628	200.0	113.6	1750	11.4	50.8	93.5	-	47.5	9.1	22.0	23,845
Qnormal	60%	5256	400.0	109.5	1750	16.0	68.9	94.5	-	65.1	12.6	31.7	66,342
Qmax	10%	876	500.0	100.0	1750	18.1	72.5	94.8	-	68.7	14.2	35.1	12,473
Weighted Average		8760	350	109.8	1750	14.8	63.8	94.2	-	60.2	11.7	29.1	102,660

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Tech Talk

"Flow Economy" Continued...

Variable Speed Pump with VSD

Flows	Time	Operating Hours	Flow (gpm)	Head (ft)	Speed (rpm)	Power (HP)	Pump Eff	Motor Eff	VSD Eff	Wire to Water Eff	Total Power (KW)	Flow Economy (gpm/kW)	kW hrs
Qmin	30%	2628	200	57.9	1272	4.9	60.1	93.7	97.6	54.9	4.0	50.3	10,450
Qnormal	60%	5256	400	81.9	1555	11.6	71.4	94.9	97.7	66.2	9.3	43.0	48,881
Qmax	10%	876	500	100.0	1750	17.4	72.6	95.0	97.7	67.4	14.0	35.8	12,250
Weighted Average		8760	350	76.5	1490	10.1	68.1	94.6	97.7	62.9	8.2	44.5	71,581

By evaluating this system purely on wire-to-water efficiency you can see that the variable speed pump system has a slightly higher efficiency then the fixed speed system 62.9% vs 60.2%. By this comparison method the variable speed pump systems shows only a 1.7% gain in efficiency which at first evaluation may not be enough to justify adding the VSD. However, using wire-to-water efficiency as a comparison does not provide the true pump system efficiency. By calculating the flow economy of these two systems you can see that the variable speed pump system yields almost a 53% improvement in the flow economy ratio (44.5 vs. 29.2) which translates into a 30% savings in kw hrs.

In this example the wire-to-water efficiency did not show a significant difference between the two pump systems. This is because efficiency does not provide a useful gauge of how much of the total energy is providing useful work. By evaluating pump systems with the flow economy ratio, the pump system can be evaluated by defining how much work can be performed for every unit of energy expended.

There are many factors that determine how efficient a pump system operates, but for maximum efficiency the entire pump system must be considered. With the rising cost of energy, evaluating pumps between the flanges is no longer an economically sound approach.

Back up information
Pump Operation Overview

By looking at the hydraulics of this system, the pump operates where the pump performance curve and system curve intersect. Since the pump is limited to a fixed speed without any regulation, the pump would produce excess flow and run out on the pump curve. To regulate the pump, the most common approach is to add a valve to the discharge of the pump. By throttling the valve, the additional frictional losses are created which steepens the system curve until it intersects the pump curve at the desired flow.

An alternative method is to adjust the speed on the pump using some form of speed regulator such as a variable speed drive (VSD). This method allows the pump to be slowed down until it intersects the system curve at the desired flow rate. This eliminates the excess pressure that is generated in a fixed speed system. This excess pressure performs no useful work and is dissipated into the pump system which directly impacts the operating cost and reliability of the pump system.