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Flow economy determines true pump system efficiency

By Daniel Kernan

ITT Corp.

A properly sized and operated pump can be one of the most efficient means of performing useful work. An average sized pump operates near 75% efficiency, compared to a combustible engine which operates at only 20% efficiency. In relative terms, a pump can be an efficient machine.

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. 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 were 50 years ago. New technologies have been slow to be adopted. With the rising cost of energy, only recently has there been a renewed focus on reducing energy cost of pumps.

Pumps and automobiles actually share many parallels. 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 a pump with an initial purchase price of \$28,000. When purchasing an automobile (Fig. 1), fuel economy makes up nearly one-third of the cost of ownership. Energy can account for as much as 75% of a pump's total cost of ownership (Fig. 2), and where the savings potential lies.

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. The pump's operation and energy efficiency is the responsibility of the pump system designer and operator.

A formula for efficiency

A pump is a machine that converts mechanical energy into pressure energy. The pressure energy is imparted into a fluid, which in turn 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. In reality, pump



Fig. 1. Fuel is nearly one-third of a car's life cycle cost, whereas the purchase price accounts for more than half.

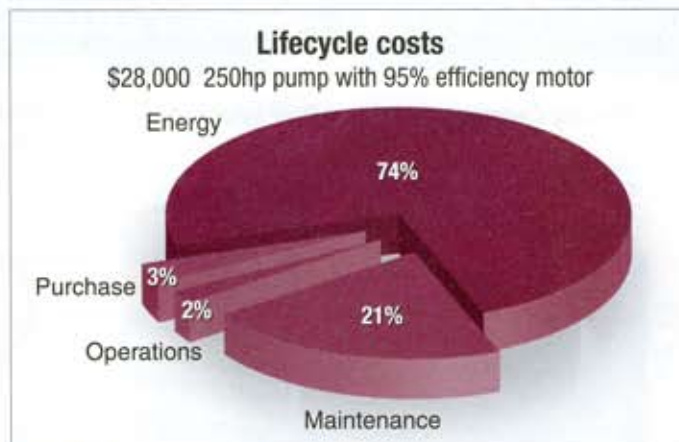


Fig. 2. The energy to operate a pump can approach 75% of its total cost of ownership.

design and efficiencies have not changed much over the last 50 years. Barring any technological breakthroughs, 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 wire-to-water efficiency, which includes all losses such as the motor and pump losses. While this provides 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 effi-

ciency; it is evaluated by fuel economy. It is a very useful metric because it defines how many miles are generated per used gallon of gasoline. If an automobile were evaluated by efficiency, then imagine operating an automobile at 55 mph all the time since that is the most efficient speed in which to operate the engine.

While the engine may be operating at the most efficient rpm, the fuel economy of the car is affected when energy is dissipated by the automobile's brakes. This is a very inefficient way to drive, and it has a negative impact on the automobile's fuel economy.

The majority of pumps are operated the same way. 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 problem with pump operation is the lack of knowledge about how much useful work the pump actually performs. If we take the same logic as the automobile industry and apply it to pumps, you can 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 divided by pump power:

This ratio means that for every kW of work being performed, the pump is able to move so many gpm.

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 an operator of a pump system the information required to quickly make decisions in the best interest of both the process and the pump.

$$\text{Flow Economy} = \frac{\text{flow}}{\text{power}} = \frac{\text{gpm}}{\text{kW}}$$

Evaluating efficiency

In the following example (Fig. 3), 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 versus a variable-speed pump system using a variable-speed drive. The system is using a centrifugal pump with varying flow rates.

By evaluating this system purely on wire-to-water efficiency, one can see that the variable-speed pump system has a slightly higher efficiency than the fixed-speed system: 62.9% vs. 60.2%. By this comparison method, the variable-speed pump system shows only a 1.7% gain in

Fixed Speed Pump with Control Valve

Rows	Wire to water Eff	Flow Economy (gpm/kW)
<i>Q_{min}</i>	47.5	22
<i>Q_{normal}</i>	65.1	31.7
<i>Q_{max}</i>	68.7	35.1
<i>Weighted Average</i>	60.2	29.1

Variable Speed Pump with VSD

Flows	Wire to water Eff	Flow Economy (gpm/kW)
<i>Q_{min}</i>	54.9	50.3
<i>Q_{normal}</i>	66.2	43
<i>Q_{max}</i>	67.4	35.8
<i>Weighted Average</i>	62.9	44.5

Fig. 3. The flow-economy ratio is a more-effective tool than wire-to-water efficiency for evaluating pump system performance.

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, one 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 kWh.

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.

Many factors 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. **PE**

Dan Kernan is product manager at ITT Monitoring & Control. He is responsible for the product life cycle management and technical support for the PumpSmart process control line. Kernan was graduated from the University of Rochester with a degree in mechanical engineering.