

Your pumps may be stealing from you

Tom Walski



There are thieves in your collection system. These thieves are the pumps that are wasting energy and costing you money every day they run. Like many thieves, these energy thieves don't advertise their presence. They look, sound, smell, and feel just like any other pump in the system. It's up to the system operator to be a conscientious detective and ferret out these bad guys.

While most features of pump system efficiency are determined during design and construction, a number of operations and maintenance practices can be implemented to either improve pumping system efficiency or restore original system efficiency.

It is impossible to simply look at a pump and determine whether it is performing in an energy-efficient manner. Calculations, field measurements, analyses, and research data recorded in pump curves are required to determine whether a pump is operating efficiently and evaluate what can be done to conserve energy.

Because considerable effort is required to locate the source of problems, improving pumping efficiency often is neglected. Even

though there are many types of and applications for pumps, this discussion focuses on the equipment and considerations used for force-main pump stations.

Pumping basics

In order to reduce energy cost, it is useful to look at the energy equation and see the terms that influence energy use and costs. The overall energy cost equation at a point in time can be written as follows:

$$\text{Energy Cost} = K \frac{Qhp}{e_p e_d e_m} \quad (1)$$

where

K is a constant, depending on the units,

Q is the flow rate,

h is the head,

p is the price of energy, and

e_p , e_d , and e_m are the efficiency of the pump, drive, and motor, respectively.



varies significantly between seasons, it also is useful to compare energy costs in different seasons. If inflow and infiltration is an issue, compare costs on wet and dry days.

Initial evaluation

Before getting into more sophisticated analysis, it is helpful to examine how the pump's current operating head and flow compare with the expected pump head characteristic curve and system head curve. Plot the pump's actual performance points on top of these curves, as shown in Figure 1 (p. 35).

The operating points in Figure 1 show what a new efficient pump's curve should look like. If the operating points do not lie on the head characteristic curve, the pump is not performing as intended due to some mechanical problem or a changed impeller.

If the points do not lie within the band of system head curves, then the system is somehow different from what was used to select the pump. This could be due to modifications in the system and may include blockages or throttled valves.

This simple plot can help point out if there is room for improvement and whether it lies in the pump or the system.

Reducing flow

Reducing pump discharge is the most direct way to reduce energy consumption. Energy savings as a result of reductions in flow typically are proportional to the amount of flow reduced and sometimes even greater.

There often are opportunities to realize savings by minimizing the flow in wastewater systems. For example, reducing infiltration and inflow into the collection system or implementing water conservation measures can reduce flow.

For constant-speed pumps discharging to a manhole, reductions in flow typically are realized at a pumping station as a reduction in the amount of time the pumps actually run, rather than appearing as a reduction in instantaneous flow rate while the pumps are running. This means that for a single pump on a pipeline, energy savings should be proportional to flow reduction.

For variable-speed pumps, reduction in flow to the pumping station appears as a decrease in the flow and head produced by the station. It will rarely reduce the duration for which the pumps run. Depending on the pump-efficiency curve, reductions in flow may result in decreased average pump efficiency.

Reducing head

Reducing the head that a pump must work against results in a proportional reduction in energy consumption, provided that the efficiency of the pump and motor do not change significantly. Because head is the result of lifting the water or overcoming friction, reduction in head can be achieved by reducing the lift or minimizing friction losses.

Little usually can be done to affect head loss or lift once a station has been constructed. Friction energy costs, on the other hand, can be reduced during pipe sizing and pump selection by selecting a size with lower head loss. There is a tradeoff involved between the construction cost of the pipe and the energy cost. As diameter increases, the construction cost increases and the energy cost decreases, as shown in Figure 2 (p. 35). But don't forget to consider minimum velocity to prevent sediment deposition in the pipe.

Each of these quantities (flow, head, price, and the three efficiencies) can be manipulated to increase or decrease energy costs. The goal is to reduce the quantities in the numerator and increase those in the denominator.

In general, before implementing any energy-use/cost-reduction equipment or procedures, it is best to simulate the results using an extended-period simulation hydraulic model, coupled with energy cost calculations. This will help estimate the expected cost savings and identify areas that might be adversely affected by the equipment or procedures.

When comparing different ways of designing and operating systems, it is important to avoid comparing efficiency or costs over too short a period. Instead, compare energy costs over a long enough period – at least a day – to account for daily flow variations and pump cycling. And instead of comparing total costs, it is helpful to compare energy costs on a per volume pumped basis – for example, dollars per million gallons pumped. Where wastewater generation

While the force-main diameter can't be changed readily, the full capacity can be restored. A force main can become partly blocked due to grease and sediment or the buildup of an air pocket. Cleaning away grease and sediment – by pigging or scraping – and installing or unclugging an air-release valve can reduce head in these cases.

Efficiency

There are three different efficiencies that must be combined to determine the overall (wire-to-water) efficiency of a pump station: pump, motor, and drive efficiency.

Pump efficiency. There is an optimal flow rate at which any centrifugal pump should operate, referred to as the "best efficiency point." But, there is no guarantee that a pump will operate at this point. The point at which a pump actually operates is determined by the intersection of the pump head curve and the system head curve. The loss of energy in a pump is due to turbulence, friction, and recirculation within the pump. The efficiency of a pump is not a constant but varies with the flow through the pump.

The goal of pump selection is to match the actual flow with the best efficiency point of the pump. The goal of good operation is to ensure that that relationship is maintained over time.

Compare actual pump flow rates with the flow at the best efficiency point. If they don't match, find and correct the problem. Solutions can vary from replacing the pump to switching the impeller to finding a throttled valve.

Drive efficiency. Variable-frequency drives (VFDs) also introduce inefficiency in pumping. Even the best VFDs result in some loss of energy. One need only feel the heat coming off an operating VFD to understand this loss of efficiency.

The efficiency of a VFD depends on a number of factors, such as size of the motor, load, and relative turndown (ratio of actual speed to full speed). It is difficult to find data on loss of efficiency as a function of turndown. Manufacturers often only give the efficiency at full speed,

a number that is of little use in evaluating VFD performance at different speeds.

In general, drive efficiency will decrease as the speed is turned down. The book *Variable Speed Pumping: A Guide to Successful Applications*, authored by the Hydraulic Institute (Parsippany, N.J.) and Europump (Brussels) and published in 2004 by Elsevier Science (New York), provides additional guidelines on the use of variable-speed pumping.

Some other factors to consider with variable-speed pumping include the following:

- Variable-speed pumping may result in low velocities that can lead to solids deposition in pipes.
- Variable-speed drives add extra components to a pumping system that can fail and require maintenance. Specify the ability to bypass the VFD if it should fail.
- Running pumps at other than their rated flow rate can result in bearing wear for which the pump was not designed.
- Variable-speed pumping tends to reduce hydraulic transients at startup and shutdown but does not eliminate transients due to power failure, which are often the worst transients.
- In general, it is better to turn off a pump (if possible) rather than run it at a very low speed.

Motor efficiency. Unlike pump and drive efficiency, motor efficiency does not vary widely with flow rate or turndown unless the load drops well below the design load. Motors can be specified with a range of efficiencies, including standard, high, and premium. With a life-cycle cost analysis, it is possible to determine whether it is cost-effective to specify a high- or premium-efficiency motor. In most cases, when a pump will run regularly – that is, it is not simply an emergency, flood, or backup pump – specifying a high- or premium-efficiency motor will be justified.

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Pumps that are wasting energy often look and sound just like other pumps in the system. The only reliable way to ensure efficiency is to use calculations, field measurements, analyses, and data. Tom Walski



Sometimes, changing pump impellers can help to improve efficiency. Coating impellers also can improve efficiency, especially in large pumps.

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Figure 1. Operating points should lie on intersection of head characteristic curve and system head curves near the best efficiency point of the pump

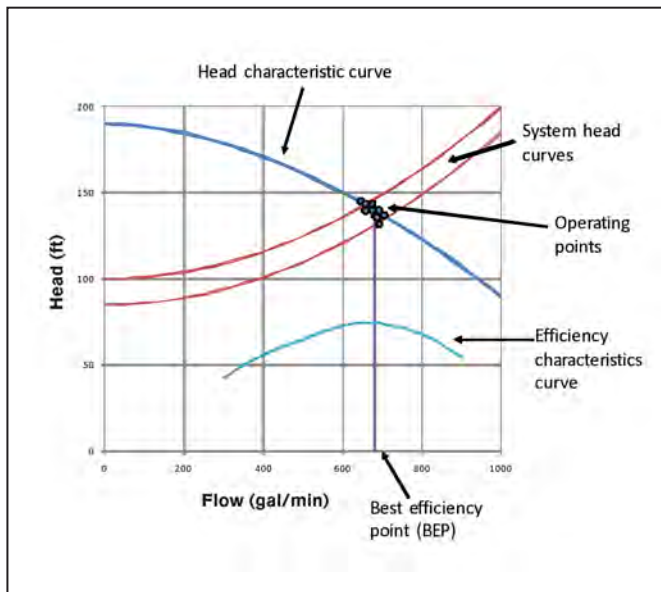
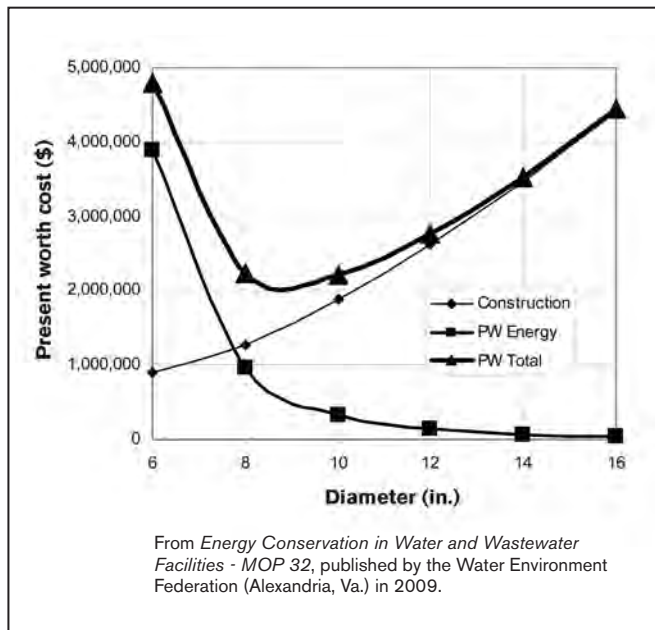


Figure 2. Tradeoff between pipe size and energy cost for force-main sizing



Energy-saving tips

There are numerous reasons for pumps not running at their best efficiency, and for every problem, there is some solution.

Energy tip	Comments
Actively look for wasted energy.	A pump will not tell the operator it is wasting energy.
Base pump selection on life-cycle costing.	Energy cost usually is the single largest cost in the life of a pump. Don't simply select a pump based on low purchase cost.
Reduce flow to be pumped.	Consider inflow and infiltration reduction for reducing pumped volume.
Maintain pumps properly.	Good maintenance can prevent deterioration of efficiency. Check clearances and replace wear rings, as needed. Check impellers for damage. Correct cavitation problems. Coating the interior of the pump may be worthwhile, especially for large pumps.
Consider variable-speed pumping for systems with small wet wells or manifold force mains.	Remember, variable-speed drives are not perfectly efficient, especially when speed is turned down.
Investigate pump combinations when selecting pumps.	Some pumps may run efficiently when run alone but perform badly when run in combination with other pumps.
Consider high- and premium-efficiency motors.	Determine life-cycle cost savings to determine if the expense is justified.
Turning off a pump saves more energy than slowing down its speed.	Some systems may need to keep a pump running at all times. However, usually it is acceptable to turn off pumps and allow wet well levels to fluctuate.
Perform field checks of pump efficiency.	Perform periodic pump-efficiency tests. At a minimum, check operating point.
Analyze tradeoffs between energy cost and force-main size during design.	Larger-diameter force mains have less head loss and can result in lower life-cycle cost as long as flow velocity is adequate to avoid sediment deposition.
Negotiate energy tariff.	Sometimes a large customer can negotiate a better energy tariff with the energy supplier.
Calculate what energy use and cost should be.	Some computer models include the capability to easily compare theoretical and actual energy use and cost.
Monitor pump-station energy bills.	Looks for trends that indicate wasting energy.
Periodically revisit pump-station energy performance.	Initially, the correct pump may have been selected, but the force-main system may have changed – for example, a new pump station was added to a common force main. Use hydraulic models to check how the system performs with new upgrades; it may indicate that the pump should be changed.