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Volume 18 Issue 1

Does Variable Speed Pressure Boosting Make Cents?

The decision to use variable speed on domestic water pressure booster pumps boils down to a question of dollars and cents. To determine if a variable speed pressure booster pump is economically justifiable, each installation must be considered as an individual case.

Bell & Gossett has developed five rules of thumb that can help you analyze whether variable speed is economically feasible for your application. These five rules address: 1) Variable head losses, 2) Pump oversizing, 3) Pressure reducing valve losses, 4) Changing system loads, 5) Changes in suction pressure.

Variable Head Losses

One major argument against using variable speed pumps on pressure booster applications is that the control curve is basically a flat line. Because proper pressure must be maintained in the system regardless of demand, pump speed range is very limited. Since pump head changes to the square of pump speed, the pump quickly exceeds the bounds of its operating range.

The argument concludes that since the system has little ability to change speed, it saves little money and is not justifiable. While these statements are generally true, they are not completely accurate.

Let's start at the beginning and examine the traditional method of sizing a constant speed pressure booster.

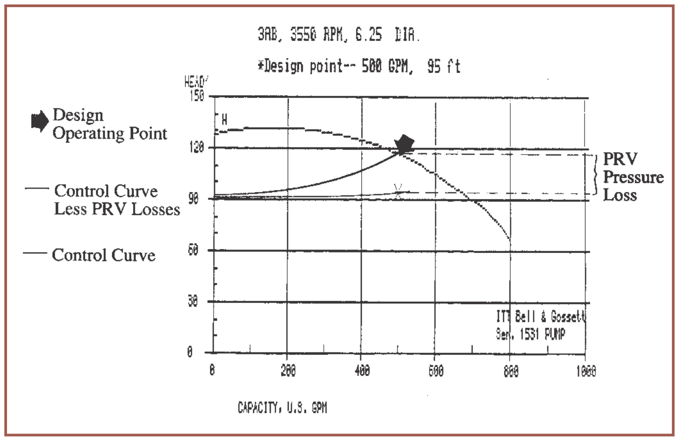

Figure 1

First, a maximum flow capacity is needed. This can be determined through a standardized sizing procedure, which totals the number of plumbing fixtures and then calculates a maximum flow by predicting how many fixtures will be operating simultaneously.

The next step is to determine the pump package discharge pressure requirement. This is accomplished by adding together the four factors below:

1) Pressure required at highest point in the system (Hr).

2) The vertical distance from the pump to the highest point (Hz).

3) The pressure losses in the system piping due to friction at full flow (Hf).

4) The pressure losses in the pump package due to the Pressure Reducing Valve (PRV) and package piping (Hk). (We'll take a closer look at the PRV later.)

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BELL & GOSSETT® NEW 70X PRESSURE BOOSTING SYSTEM

Bell & Gossett has introduced the new 70X variable speed pumping system for pressure booster applications. 70X packages are designed to provide low initial cost, outstanding reliability, and lower life cycle cost.

Using the latest proven software technology, the 70X introduces the concept of combining a variable speed lead pump with one or two constant speed lag pumps. The 70X allows the operation of multiple pumps in parallel, discharging into a common header that supplies a domestic water piping system. Variable speed pumping allows the discharge pressure of the pump to precisely match the actual system requirement.

A typical 70X package includes up to three vertically mounted Bell & Gossett Series1531 pumps with a check valve on the discharge of the variable speed pump, and one or two constant speed lag pumps, each with a pressure reducing valve. In common installations, such as multi-level buildings and schools, the system adapts to water needs as they vary over the course of the day and throughout the changing seasons.

The 70X system is controlled by the Bell & Gossett Technologic 500X pump controller that combines a variable speed drive and pump controller. The Technologic 500X uses a combination of kW, pressure and speed to calculate the most efficient operation and maintain a pre-programmed set point.

Designed with ease of installation in mind, the 70X requires only suction and discharge connections and one power connection. It also requires minimal floor space and can be transported easily through doorways, making it ideal for retrofitting.

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The pump suction pressure (source supply pressure, or Hs) is then subtracted from the sum of these four items, giving the required pressure boost of the pump package.

Boost = Hr + Hz + Hf(max) + Hk - Hs

Figure 1 (page 1) shows a typical pump curve for a constant speed pressure booster using a PRV. The conditions for this example are shown below.

Design Flow (maximum) = 500 GPM

Required Discharge Pressure = 65 PSIG

Minimum Suction Pressure = 25 PSIG

Required Pressure Boost = 40 PSIG

Constant Speed

The control curve consists of two components. The first is the pressure boost requirement, which remains constant. If the control curve consisted only of the pressure boost requirement, the curve would be completely flat.

The second element of the control curve is the variable head loss through the pump package piping with the PRV fully open. The differential head between the control curve and the pump curve is absorbed by modulating PRV. Thus, when demand is less than full load, the pressure on the discharge side of the PRV remains constant.

Variable Speed

Figure 2 shows that the control curve is relatively flat and a variable speed pump would have little opportunity to change its speed, However, if the variable speed package had to maintain a constant pressure at the discharge of the package, the control curve would be flat. But by placing the pressure sensor at the high point in the system, the control curve incorporates the variable head losses in the system piping.

The variable speed system then has the ability to follow the steeper system curve, slow down and save money. Since pump horsepower changes to the cube of the speed, even small changes in speed can have a significant effect on operating costs.

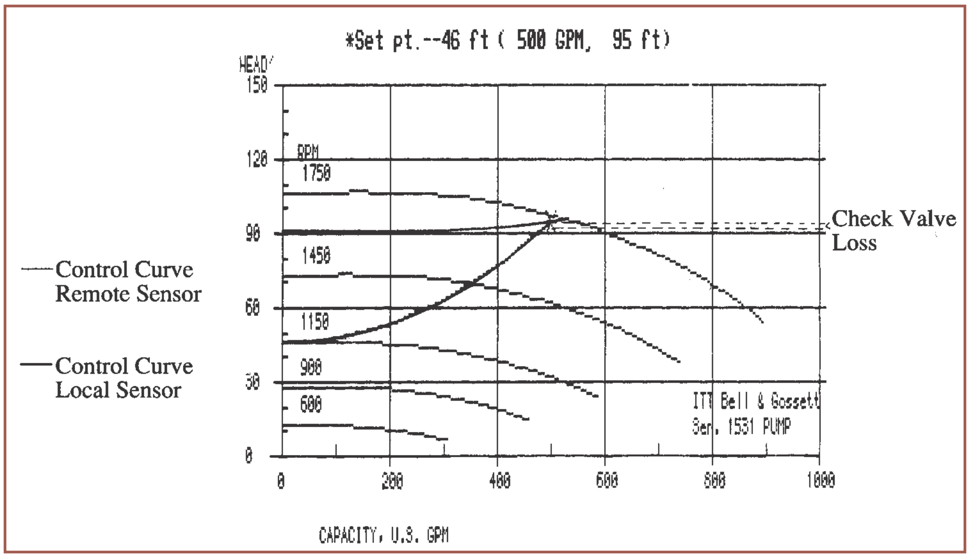

Figure 2

It may be easier to understand by looking at the system setpoint. The setpoint is the pressure the variable speed control system will try to maintain at a specific location. If the pressure sensor is located at the discharge side of the pump package, the setpoint will be equal to the total of the pressure required at system high point, the vertical distance to the high point, and the piping friction loss at full capacity. This total will ensure that the package is always producing enough pressure to satisfy the worst condition.

Setpoint = Hr + Hz + Hf (max)

Control Curve = Setpoint + Hk - Hs

By placing the sensor at a remote location in the system, most likely the highest point, the setpoint will be equal to the required pressure at that point. For example, if the objective is to have 25 PSIG at the highest point in the system, then a sensor at this location will have a setpoint of 25 PSIG. The control curve for a system with a remote sensor will have a steeper slope, allowing for a greater reduction in speed (refer to Figure 2).

Setpoint (remote sensor) = Hr

Control Curve

(remote sensor) = Hr + Hz + Hf + Hk - Hs

The sum of the fixed head elements (Hr + Hz - Hs) is the point where the control curve crosses the Y-axis. It becomes obvious that the lower the curve intersects the Y-axis, the better the opportunity the variable speed system has to slow down and save money.

A piping system which has a higher ratio of variable head losses to fixed head elements will be a better candidate for variable speed than a system with a lower ratio.

It should be noted that the type of building and application become important factors in determining the economic benefits of variable speed. A tall residential apartment building will have a very different fixed head/variable head ratio than a large, sprawling one-level factory.

Pump Oversizing

Pumps for pressure booster applications are typically oversized for several reasons. The system load is calculated based on the number of plumbing fixtures and a conservative estimate of how many plumbing fixtures will be in operation simultaneously.

Specifying engineers use a safety factor to guarantee that the pump is not undersized. An undersized pump results in an unhappy customer, and in cost penalties to correct the situation. But an oversized pump will result in a system that still

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works and has some standby capacity.

An underestimation of suction pressure results in pump oversizing. The use of an underestimated suction pressure may be justified due to a lack of suction pressure history, an expected drop in suction pressure because of an aging system, or a municipality which may not keep pace with population growth.

An additional reason for an overheaded pump is that piping head losses are calculated using tables with built-in safety factors or to accommodate plans for future expansions.

All of this adds up to higher operating costs. In fact, a pump that is 25% overheaded costs approximately 25% more to operate; a 50% overheaded pump will cost approximately 50% more to operate. Although this can be alleviated by trimming the pump impellers, this practice is rarely followed.

To protect a constant speed system from overheading, a pressure reducing valve (PRV) is typically installed on the pump discharge. When a pump is overheading, the excess energy is absorbed by the PRV. This excess energy is money down the drain.

With a variable speed system, the pump produces only enough head to satisfy the desired discharge pressure requirement. The excess capacity is available if it is ever needed, but while in reserve, it is not needlessly consuming energy.

Variable speed systems also allow for system fine tuning. Once a system is installed and operating, the setpoint can be adjusted to find the lowest point where the system is still satisfied. This allows for optimal system performance with minimal effort, and without the additional expense of trimming impellers.

Pressure Reducing Valve Losses

A pressure reducing valve (PRV) is used on many open systems as a means of pressure control. The PRV modulates open and closed to maintain a constant discharge pressure regardless of changes in system demand or suction pressure. It has a design pressure drop across it that must be accounted for in the selection of the pump.

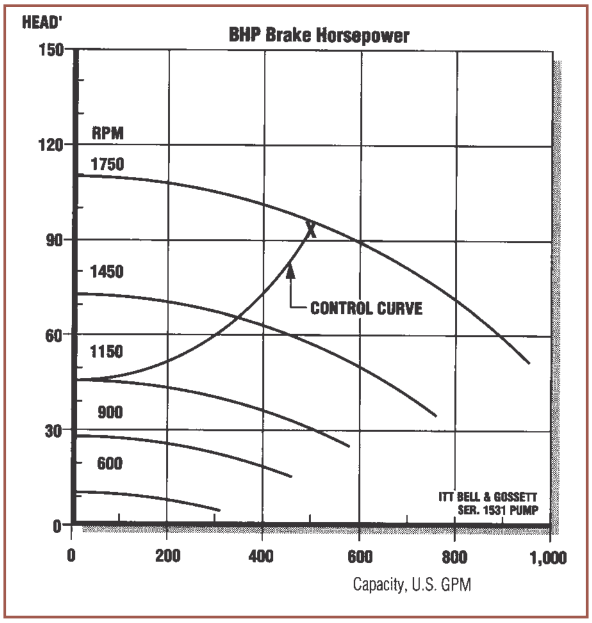

Figure 3

However, with variable speed pumps, there is only a nominal added pressure drop through a check valve.

A typical pump curve for a constant speed pressure booster system uses a modulating PRV on the discharge side of the pump to maintain a constant discharge pressure on the system. This conventional set-up clearly demonstrates the extra head required by the pump due to the PRV.

For this constant speed system with a four inch PRV, the Brake Horsepower (BHP) at design conditions = 19.3 BHP, based on the 500 GPM at TDH (40 PSIG boost plus PRV pressure losses and package piping loss).

Figure 3 shows an example of a variable speed pressure booster that speeds up or slows down as system flow demands increase or decrease. This set-up is more efficient to operate because the pump is only generating the required head needed for current system conditions. The only additional head loss is due to the check valve on the discharge side of the pump.

For the variable speed pump, BHP at design conditions = 15.2 BHP based on 500 GPM at 95TDH (40 PSIG boost plus the pressure loss through the check valve and package piping).

Figure 4 compares the two pumps at partial load and graphically shows the difference in required water horsepower.

$$\text{Water Horsepower} = \frac{(\text{Flow}) \times (\text{Head}) \times (\text{SG})}{3960}$$

At a reduced flow of 225 GPM, the water horsepower saved = 4.3 HP. By taking pump efficiencies into account, we calculate the brake horsepower saved = 9.6.

Changing System Loads

The cited example is based on just one operating point. Through the use of ESP-PLUS equipment selection software, available from Bell & Gossett, we can take into account different variables affecting the pressure booster system, including changing loads, as well as compare annual operating costs (AOC).

As is true with most systems, full load conditions occur only a small percentage of the time. Since horsepower varies to the cube of a change in speed, energy is saved at a greater rate the more a pump slows down. In our example system, where a majority of the time the pump is operating at reduced loads, the energy savings is dramatic.

Other variables need to be taken into account to obtain a realistic annual operating cost include changing pump, motor and drive efficiencies. A good equipment selection software package will use accurate component efficiences which vary depending on changes in speed and load in order to obtain accurate system modeling.

Through computer modeling with ESP-

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PLUS, we learn the example variable speed system is estimated to save $6,040 a year in operating costs.

Changes In Suction Pressure

All of the benefits of using variable speed pumping that we covered in this article so far are compounded when there is an increase in suction pressure. When selecting a pressure booster pump, the lowest suction pressure that will supply the pump is used as the basis for pump sizing. This technique is utilized to ensure the pump will be sized large enough to satisfy system requirements whenever the suction pressure is at its lowest point.

With constant speed pumps, whenever the suction pressure is higher than the stated minimum, energy is being wasted because the PRV absorbs the excess pressure the pump is generating. Conversely, variable speed pumps operate much more efficiently by slowing down when suction pressure rises, and only operating at the required load. Figure 5 depicts the horsepower saved when comparing variable speed to constant speed pumping with a 15 PSI increase in suction pressure.

You will note that when the suction pressure increases above the stated minimum, the control curve is lowered by an equal amount. Put simply, the pumps do not have to produce as much pressure. Revising our comparison of constant versus variable speed to include varying suction pressures, the estimated annual operating cost savings is $7,018.

Payback Analysis

The final test to determine if a variable speed system is economically justifiable is to perform a payback analysis. For this payback example, we will use one 100 percent duty pump, two 50 percent duty pumps and a three pump system (20/40/40 percent). The following table demonstrates that this system, like most, is a very attractive variable speed candidate.

In addition to the economic benefit, variable speed pressure boosting has all the advantages of other variable speed applications. These include inherent soft-start (both electrical and mechanical), good system control and full system back-up capability

		1 PUMP	2 PUMP
CONSTANT SPEED	1 PUMP	1.5 YEARS	2.8 YEARS
	2 PUMP	1.5 YEARS	3.2 YEARS
	3 PUMP	0.6 YEARS	2.6 YEARS

Contact Wallace Eannace Associates, your local B&G Representative, to detimine if variable speed pressure boosting makes "cents" for you.

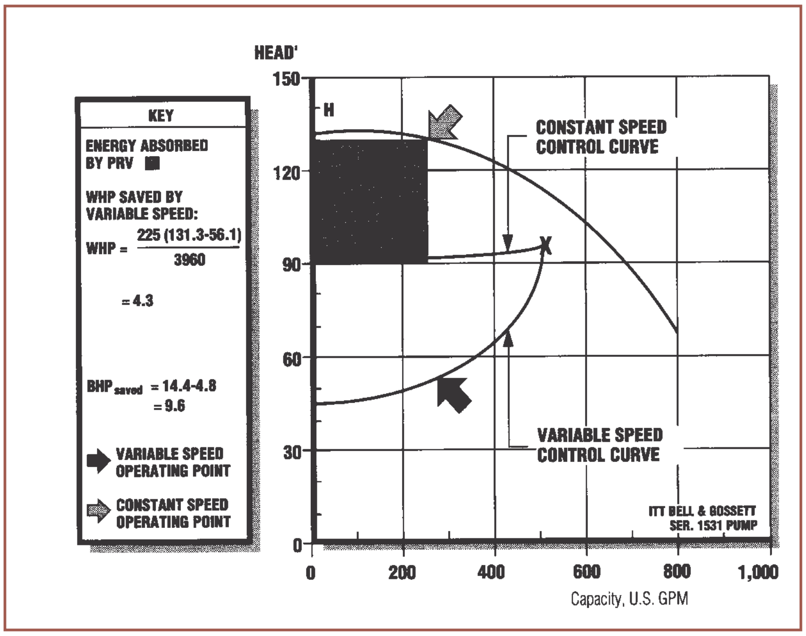

Figure 4

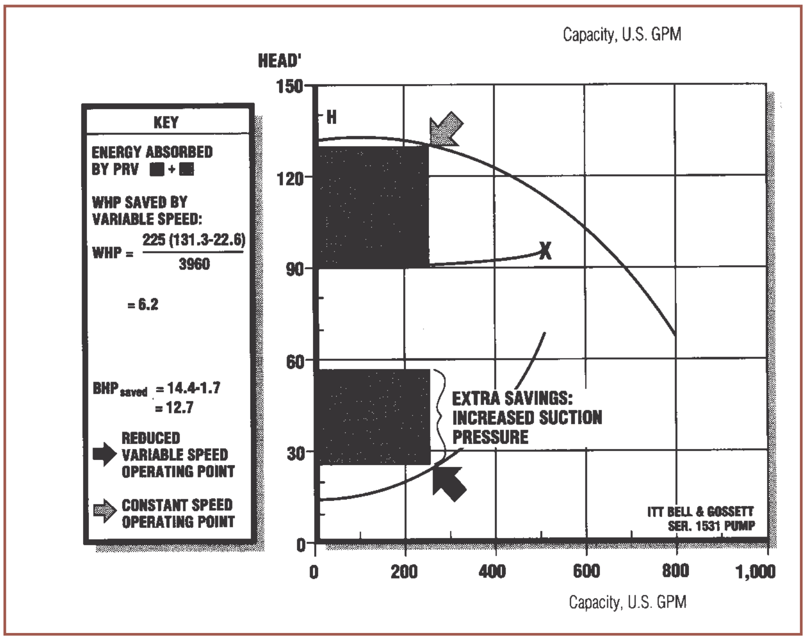

Figure 5