The fundamentals about pump efficiency and control

With more focus on building energy efficiency, building owners often rely on consulting engineers to specify efficient pumping solutions. For variable flow systems, this poses some challenges when parallel pumps are being evaluated.

A recent international webinar by Reece Robinson of Grundfos Pumps Corporation hit the pause button to review some of the fundamentals when talking about pump efficiency and control.

From the get go, before one can talk about efficient pump selection and control, it is essential to understand the pump performance curve, says Robinson.

"It is important to understand what are the different parts of the curve and how they relate to varying the speed and overcoming pressure and things like that," he says.

Points on a pump performance curve

Shut-off head, sometimes also referred to as dead head, is the point of zero flow.

"This is operating the pump against a closed valve which you don't want to do for a long time as damage from heat buildup can occur. Heat in the pump casing occurs and ultimately you have damage in the seal," he says. "So, when we look at pumps and control, the goal is to avoid pumps running at this point for very long. We don't want to operate the pump in shut-down."

The operating point is where the system curve intersects the pump performance curve. "This where the pump is actually running," says Robinson. "You might have what is a called a duty point. This is the actually what is designed for. The designer comes up with a flow and a head and will assign numbers to it based on calculations."

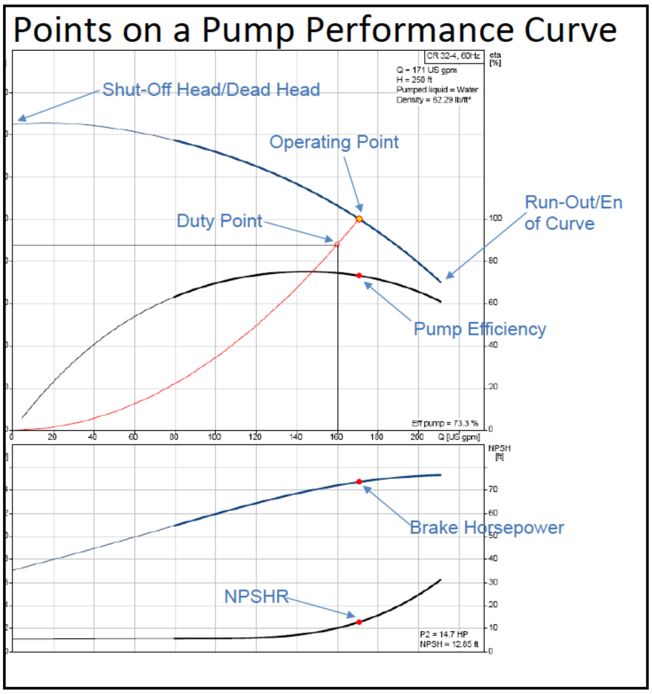
According to Robinson these are the desired conditions, but when the pump is switched on, it usually outperforms that which requires the throttling of control valves or the balancing of valves to get the pump back where it is wanted. "Controls like variable speed drive is also used to reduce the pump performance to hit that point. The operating point is where the pump is actually running and the duty point is what it was designed for. Sometimes those two are not the same."

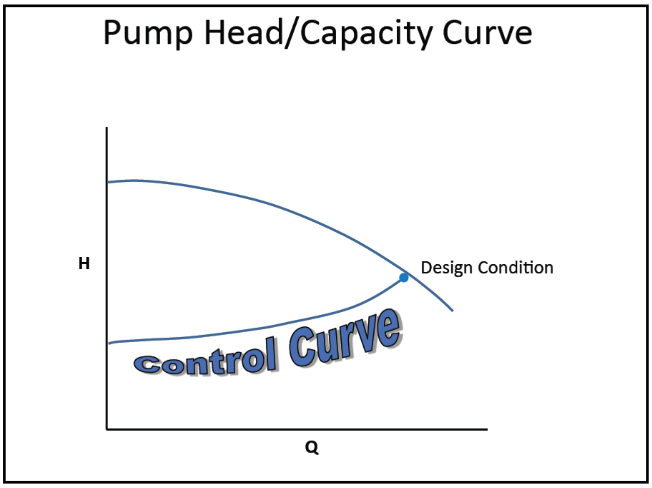
Run-out or end of curve is the maximum allowable flow rate for the pump. "Flows exceeding this should be avoided," says Robinson. "Running pumps here for a long time is not advised as it results in lower life time as it outside the pump's preferred operating range. It increases the inner serviceable of the pump. It does cause damage."

Pump efficiency refers to the pump hydraulic efficiency and does not typically include the motor efficiency. In most cases it is preferred to run this where the pump is most efficient (also referred to as the knee of the curve that is ranged from high flow to low flow).

Brake horsepower is the horsepower required by the pump. "This is the shaft output power for the pump and as flow increases so does the pump brake horsepower," says Robinson. "This is not to be confused with nominal horsepower. You might have a 20-horsepower motor on the pump but as that pump is operating from low flow to high flow it will load that motor according to the amount of liquid it is moving and the pressure it is overcoming."

According to Robinson any point on this curve should be lower than the motor nameplate horsepower.





The Affinity Laws

for centrifugal pumps

Flow varies linearly with pump speed > $\frac{GPM_1}{GPM_2} = \frac{RPM_1}{RPM_2}$ > $GPM_2 = GPM_1\left(\frac{RPM_2}{RPM_1}\right)$

Head varies with the square of the pump speed > $\frac{TDH_1}{TDH_2} = \left(\frac{RPM_1}{RPM_2}\right)^2$ > $TDH_2 = TDH_1\left(\frac{RPM_2}{RPM_1}\right)^2$

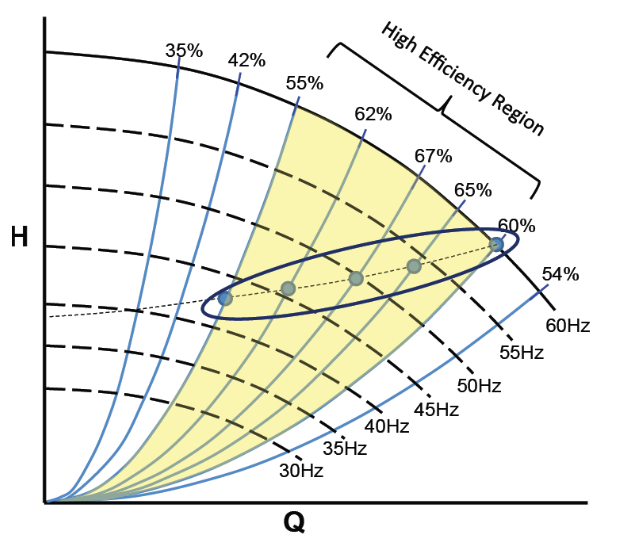
Brake Horsepower varies with the cube of the pump speed > $\frac{BHP_1}{BHP_2} = \left(\frac{RPM_1}{RPM_2}\right)^3$ > $BHP_2 = BHP_1\left(\frac{RPM_2}{RPM_1}\right)^3$

When TDH_1, RPM$_1$ and TDH_2 are known:

$$RPM_2 = RPM_1\sqrt{\frac{TDH_2}{TDH_1}}$$

1 = Original condition (full speed)
2 = New condition (reduced speed)

Curves of constant efficiency with speed reductions



Net Positive Suction Head (NPSH), often jokingly referred to as not pumping so hot, is a value that must be paid attention to, says Robinson. “You must make sure you have enough suction head to keep the pump operating optimally. It is very important in boiler feed systems and systems with flooded suction. It is not that important for cold water from a pressurized source or for hydronic heating and cooling systems.”

System Curve

This, says Robinson, is a simple curve that represents the friction loss in a system as the flow changes.

“The quadratic relationship between flow and friction loss, means that if you know the head and flow of the system at any point in time, you can calculate the head for each corresponding flow point and draw a curve.”

Control curve

“When one is talking about efficient pumps, it is really about running the pump at its preferred operating range for the longest periods of time,” explains Robinson. “When we talk about pump control with variable flow then running it at that exact point is very rare. The goal is thus to stay in the zone, those areas closest to that most efficient point.”

He says to know whether one is going to do this it is important to know how to control the pumps.

The control curve is similar to the system curve but it begins with a minimum head at zero flow.

“In most applications head is going to increase as the flow increases. In some applications will have extremely low head, but that would be a totally friction dominated system but the real world shows us that to have some kind of fixed head you need to overcome static head. In distributed HVAC flow, there are coils and a certain amount of head must be present in order to establish satisfactory flow. The control curve represents a theoretical calculation of where a variable speed pump will operate at part load.”

Pump affinity Laws

Varying the speed of a pump means understanding the affinity laws. These laws define the mathematical relationships between flow (GPM), pump speed (RPM/change in impeller diameter), head and brake horsepower (BHP).

They are:

1. Flow varies linearly with pump speed
2. Head varies with the square of the pump speed
3. Brake horsepower varies with the cube of the pump speed.

Robinson says it is important to remember that the affinity laws assume constant pump efficiency. “The pump can only run continuously at its best efficiency point along a system or control curve that follows a curve of constant efficiency.”

If one introduces constant pressure, says Robinson, as flow reduces so will the pump efficiency. Therefore, when selecting pumps for variable flow it is important to select pumps based on a design flow that is to the right of the pumps best efficiency point.

Garnett Cross Hydraulic Courses C.C.

Correct and regular maintenance will result in hydraulic equipment lasting for many years

Registered with SAIMechE / Engineering Council of SA iro CPD

Email – garnett@cross.co.za * Tel. 011 453-8063 * www.garnettcross.com