How to Read a Pump Curve

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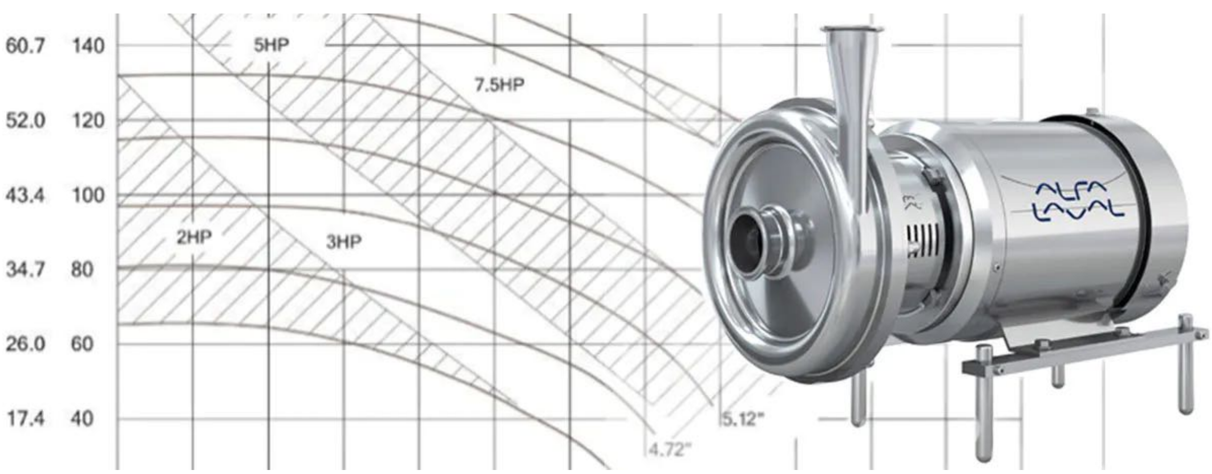
How to read a pump performance curve remains a topic of great interest across the food, dairy, beverage, and pharmaceutical processing industries, so in this post we provide important information on two of our most popular styles — **Centrifugal and Positive Displacement.**

> A pump performance curve helps you select the right pump for the specific needs of your application.



Centrifugal Pump Curve

Also called a pump selection curve, pump efficiency curve, or pump performance curve, **a pump curve chart gives you the information you need to determine a pump's ability to produce flow under the conditions that affect pump performance**. Reading pump curves accurately helps you choose the right pump based on application variables such as:

- Head (water pressure)
- Flow (the volume of liquid you have to move in a given time period)

As you will see, you can also use pumps in parallel to increase flow.

This pump curve explanation also discusses variables such as:

- RPM
- Impeller size, as they related to pump performance
- Power
- Efficiency
- Net Positive Suction Head (NPSH) in centrifugal and positive displacement pumps

For example, if you know the flow rate your application requires, you find the gallons per minute (or hour) rate along the bottom horizontal line of the curve and then draw a line up to the head/PSI you require. The curve will show you if the pump you have selected will perform in that application.

1. HOW TO READ A CENTRIFUGAL PUMP PERFORMANCE CURVE?

Curves typically include performance metrics based on **pressure, flow, horsepower, impeller trim, and Net Positive Suction Head Required (NPSHr).**

Centrifugal pump curves are useful because they show pump performance metrics based on head (pressure) produced by the pump and water-flow through the pump. Flow rates depend on pump speed, impeller diameter, and head.

What is Head?

Head is the height to which a pump can raise water straight up. Water creates pressure or resistance, at predictable rates, so we can calculate head as the differential pressure that a pump has to overcome in order to raise the water.

Common units are feet of head and pounds per square inch. (A pump curve calculator might offer different units such as Bar or meters of head). As Figure 1 illustrates, every 2.31 feet of head equals 1 PSI.

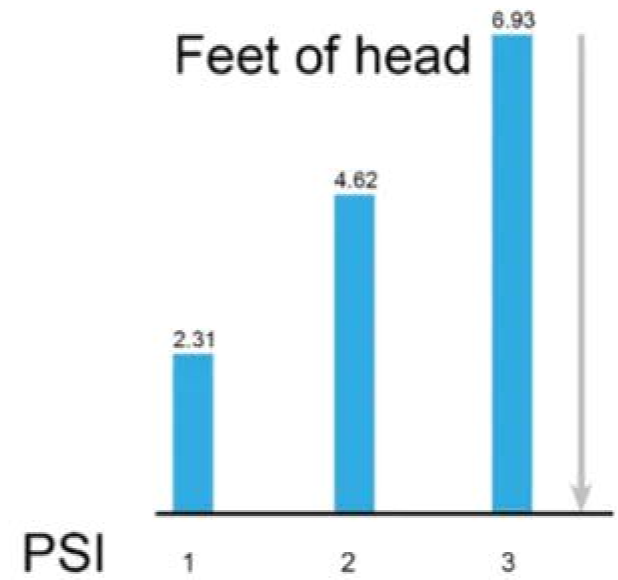


Fig 1. Every 2.31 feet of head creates 1 PSI of pressure.

The Formula for PSI: Feet of Head/2.31 = PSI

Flow is the volume of water a pump can move at a given pressure. Flow is indicated on the horizontal axis in units like gallons per minute, or gallons per hour, as shown in Figure 2.

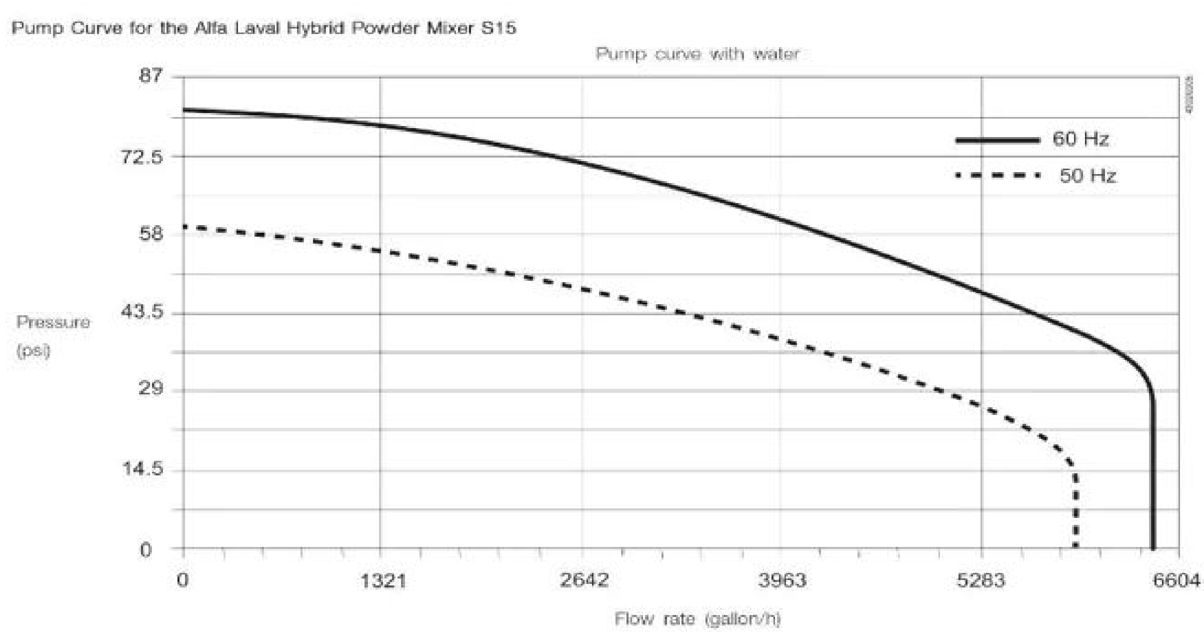


Fig. 2. A basic pump performance curve for centrifugal pumps show it's performance range. In this curve, head is measured in PSI; flow is measured in gallons per hour.

What is Total Dynamic Head?

While pump curves help you select the right pump for the job, you first have to know the total dynamic head for the application.

> Total Dynamic Head (TDH) is the amount of head or pressure on the suction side of the pump (also called static lift), plus the total of 1) height that a fluid is to be pumped plus 2) friction loss caused by internal pipe roughness or corrosion.

TDH = Static Height + Static Lift + Friction Loss

- Static Lift is the height the water will rise before arriving at the suction side of the pump.
- Static Height is the maximum height reached by the pipe on the discharge side of the pump.
- Friction Loss (or Head Loss) are the losses due to friction in the pipe at a given flow rate.

Learn more about centrifugal pumps and key calculations.

How to Use Performance Pump Curves in Selecting Equipment: The Basics

Let's say you want to know the flow rate you can achieve from the pump in Figure 3 at 60 Hz when the design pressure is 80 PSI. In this case, the curve shows that the pump can achieve a flow rate of 1321 gallons per hour at 80 PSI of discharge pressure.

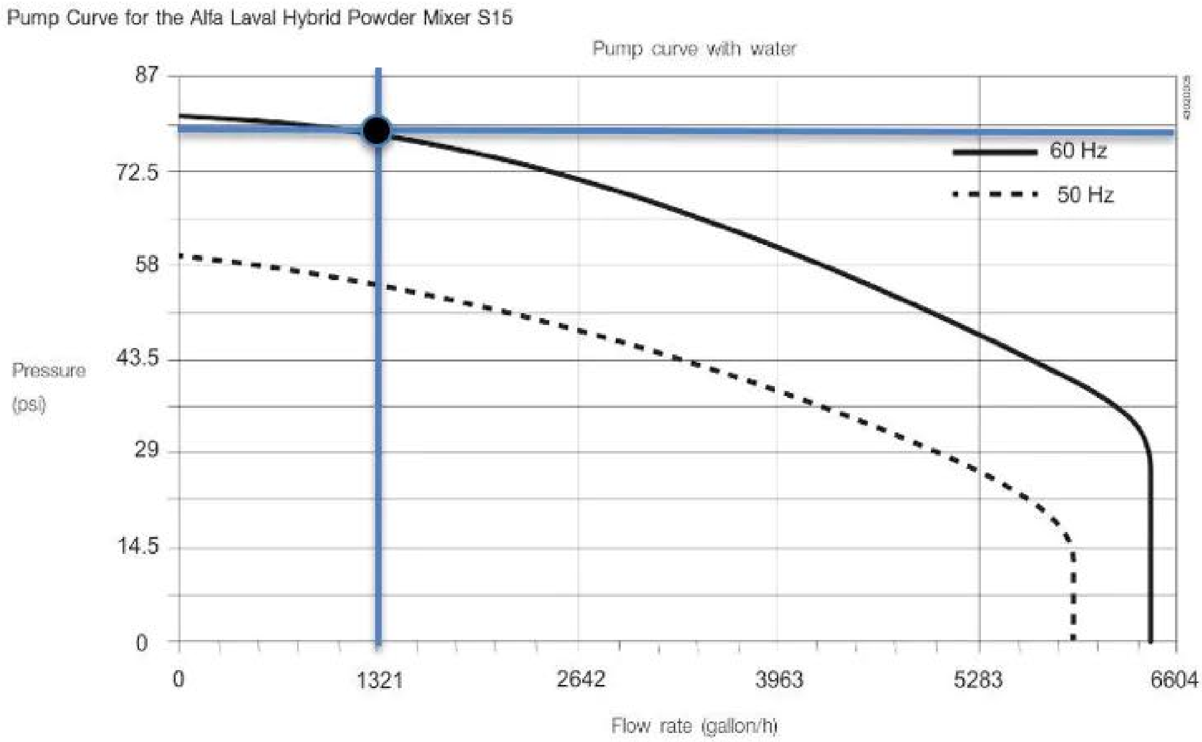


Fig. 3. In this pump performance curve, he pump can generate 80 PSI of discharge pressure at a flow rate of 1321 gallons per hour. Pump curve charts indicate flow rates on the horizontal axis and pressure on the vertical axis.

Reading Centrifugal Pump Curves that Contain Additional Information

Because some centrifugal pumps operate across a range of horsepower, their curves will include additional information. Figure 4, for example, features a pump that can operate from 2 to 10 horsepower depending on desired performance.

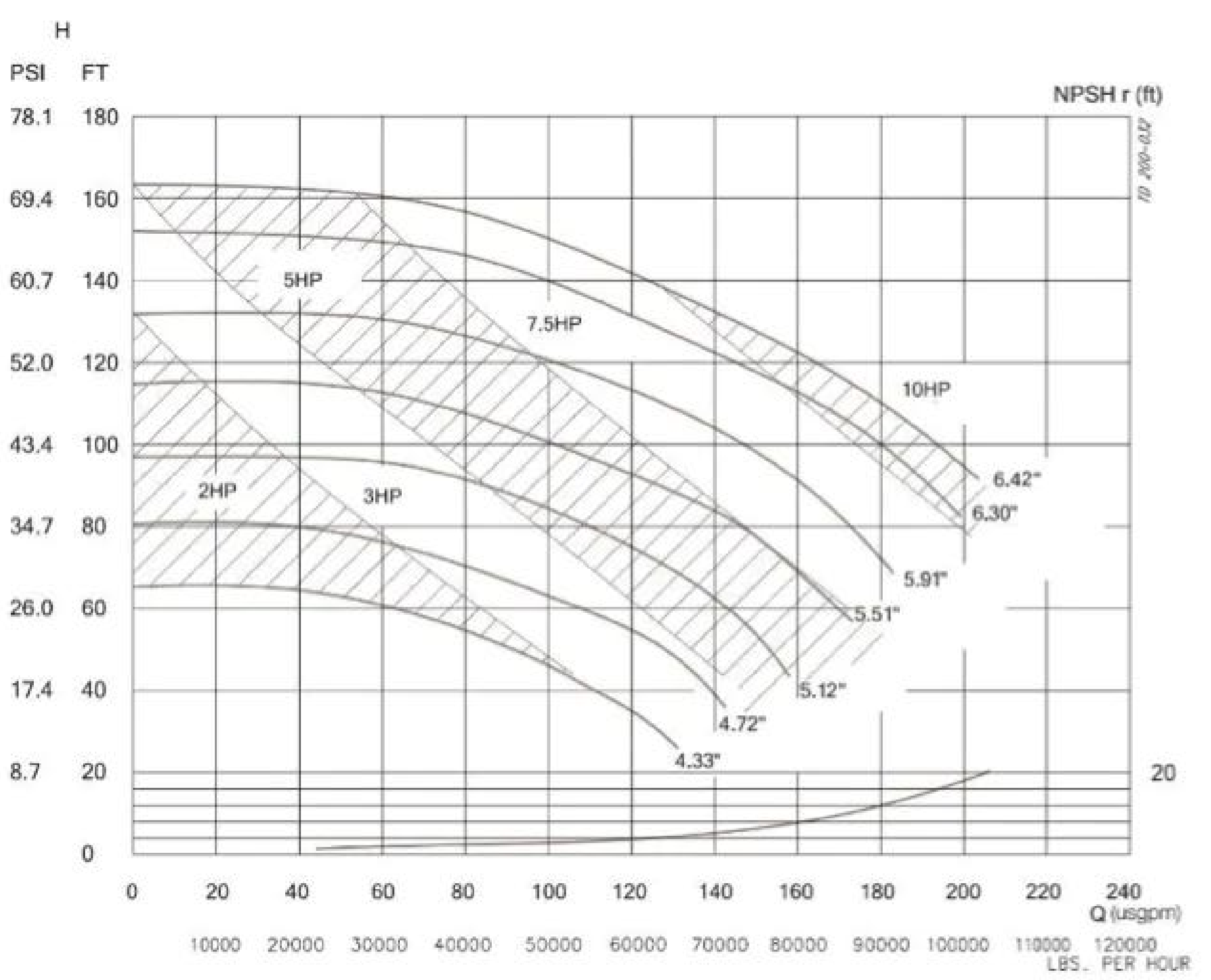


Fig. 4. Variable Horsepower pumps can operate at a range of head/flow combinations and impeller trim sizes.

For additional curves, see Alfa Laval LKH performance curves.

Impeller Trim Size

Impeller size is another variable for meeting performance requirements. The curve above shows impeller trim sizes, at the right end of each curve, ranging from a minimum of 4.33" to a maximum of 6.42".

Reducing impeller size enables you to limit the pump to specific performance requirements. The curve above shows maximum pump performance with a full-trim impeller, minimum pump performance with a minimum-trim impeller, and performance delivered by the design-trim impeller, or the impeller trim closest to the design condition. Impellers are typically trimmed 0.20 inches (or 5mm) at a time.

Impeller size is also a factor when handling shear sensitive liquids, or liquids that change viscosity when under pressure.

Net Positive Suction Head Required/Available

In addition to pressure and flow, the curve at the bottom of Figure 4 indicates NPSHr, which stands for Net Positive Suction Head Required. **NPSHr is the minimum amount of pressure required on the suction side of the pump to avoid cavitation**, or the introduction of air into the fluid stream. NPSHr is determined by the pump. You always want NPSHa>NPSHr.

NPSHa, with "a" standing for **available**, is determined by the process piping.

> You always want NPSHa to be greater that NPSHr. Without enough net positive suction, the pump will cavitate, which affects performance and pump life.

Efficiency and Performance Variables

Good pump efficiency means that a pump is not wasting energy in order to maintain its performance point. No pump is 100% efficient, however, in the work it has to do to transfer liquids.

When selecting a pump and motor combination, consider not only the total current demand but future demand to ensure your selection has the capacity to meet changing requirements. To that end, **sizing the pump for performance variables rather than peak efficiency is a common practice.**

For example, **while the middle of the pump efficiency curve is generally where a pump is operating at maximum efficiency in terms of pressure and flow rate**, moving right on the curve above shows an increase in horsepower needed to maintain a flow rate as head increases. For example, 2 hp is required for a flow rate of 40 gpm with 80 feet of head, but maintaining 40 gpm of flow at 110 feet of head would require a 3 hp motor.

You can audit pumping systems using pump performance characteristics. Once you determine the best efficiency point (BEP) for your application, you can make adjustments to improve overall system efficiency, such as adding a variable frequency drive (VFD) and changing the diameter of the pump impeller. Controlling flow rate by adjusting pump speed via VFD instead of pressure valves can result in better efficiency and greater energy savings.

When using pumps in parallel, you can increase flow rate at the same rate of head. As figure 5 illustrates, using pumps in parallel gives you a flow rate that is the sum of pump A and pump B’s flow rates.

Finally, variable speed pump curves show flow rates at various RPM, as shown in Figure 6.

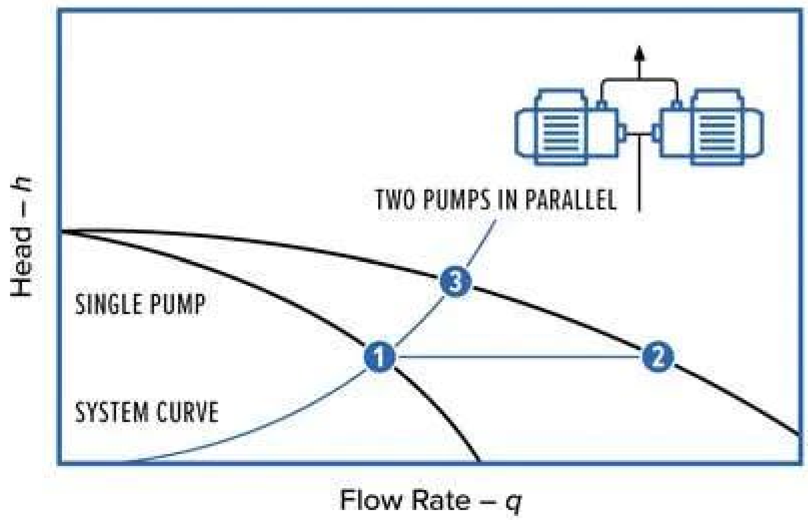


Fig. 5. Assuming two identical pumps, flow rate doubles when used in parallel. The system curve shows the rate of pressure loss. As flow rate increases, pressure loss increases.

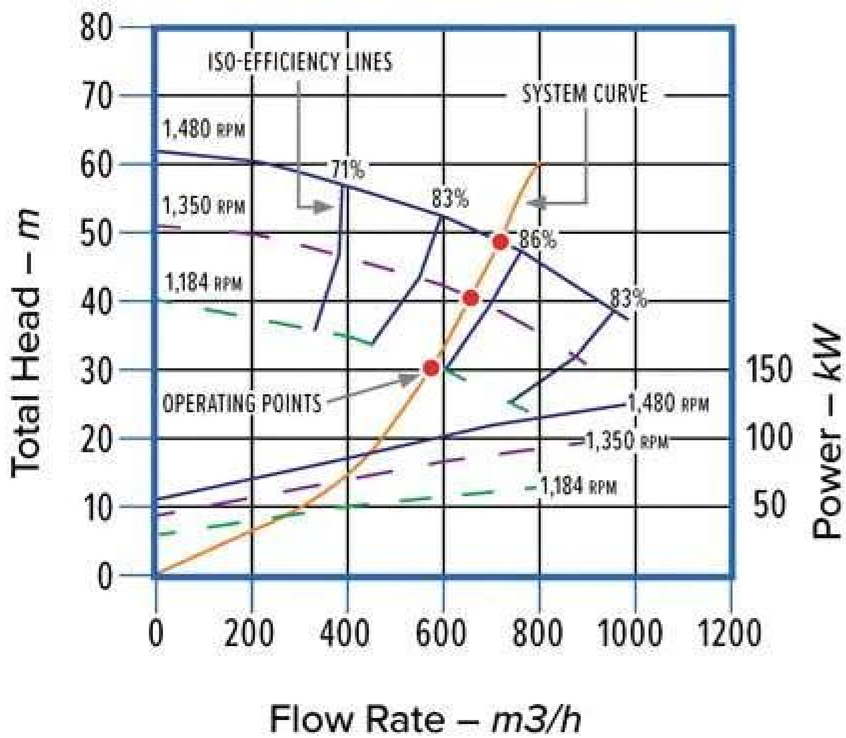
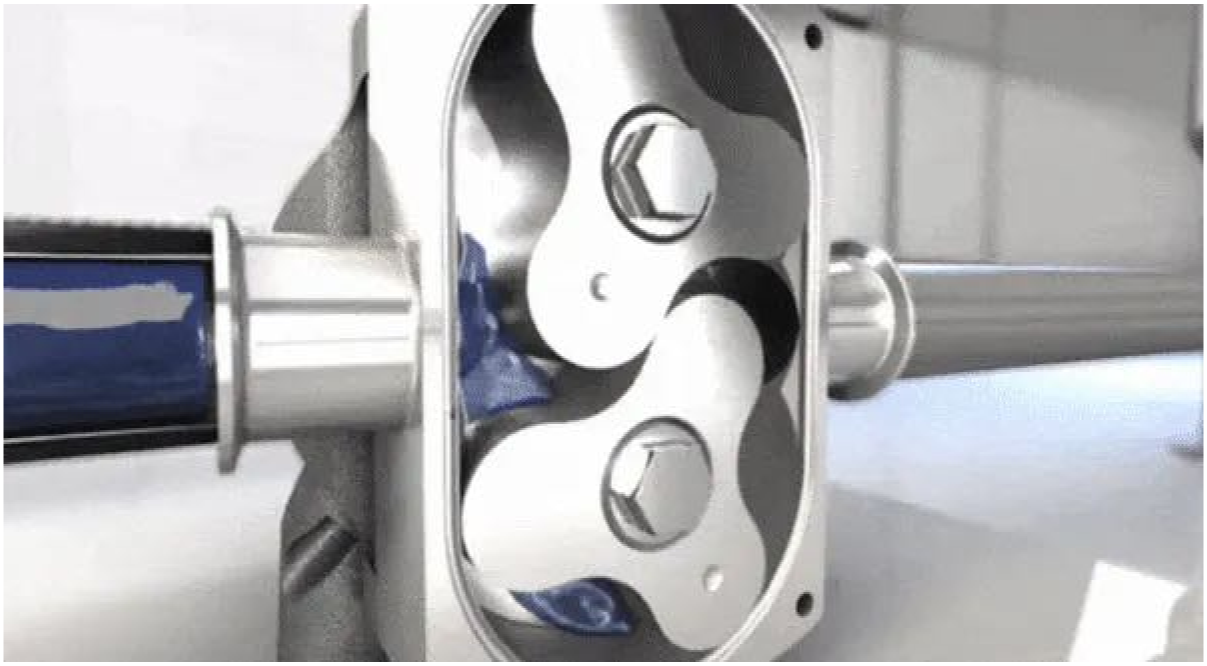


Figure 6



Alfa Laval Optilobe Series PD Pump

2. How to Read a Positive Displacement Pump Curve

A positive displacement (PD) pump produces the same flow at a given speed (in revolutions per minute--RPM) no matter what the discharge pressure. Positive displacement pump curves give you the information you need to determine a pump's ability to produce flow under the conditions that affect pump performance.

PD pumps come in a variety of mechanical designs, to name a few:

- Circumferential Piston Pumps
- Rotary Lobe Pumps
- Twin-Screw Pumps
- Progressive Cavity Pumps

A Positive Displacement Pump Curve answers several important questions during the pump selection process:

1. What flow rate is the pump capable of?
2. How much does slip affect the pump’s ability to perform?
3. How much HP is required for the anticipated pressure?

> Curves answer those questions by displaying intersections of several important variables, including capacity, work horsepower, viscous horsepower, and Net Positive Suction Head required (NPSHr).

Capacity

Capacity, as illustrated in Fig. 7, is the volume of fluid a pump can displace by RPM.

As RPM increases, the pump flow increases, from 0 gallons per minute or (GPM) at 0 RPM, to about 130 GPM at 500 RPM. Remember that some performance curve calculators might include units such as liters per minute (LPM), so check calculation units when using calculators.

> **Fig. 7**. A PD pump curve indicates pump capacity, on the horizontal lines, in units per minute. In this example, the curve indicates **gallons per minute (GPM)** and **liters per minute (LPM)** in the left margin and the vertical lines indicates pump speed in **revolutions per minute (RPM)**.

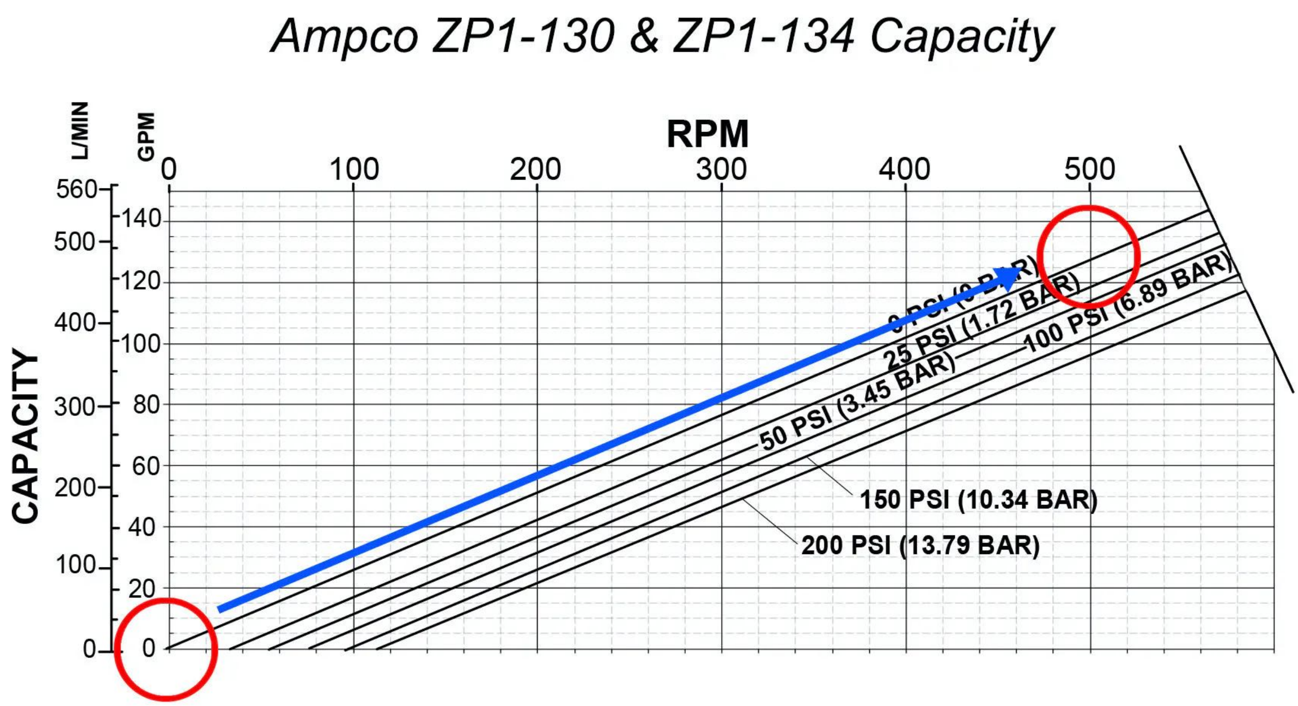


Figure 7

The importance of viscosity in pump selection

Positive displacement pumps deliver a constant flow of fluid at a given pump speed. When viscosity increases, however, resistance to flow increases, so to maintain system flow at higher viscosities, pumps require more horsepower.

Low viscosity also affects pump performance in the form of slip. **Slip is the internal recirculation of low viscosity fluid from the discharge side of the pump back to the suction side of the pump.** The amount of slip in a PD pump is influenced by the fluid's viscosity and the discharge pressure.

> As discharge pressure increases, keeping viscosity constant, more fluid slips from the discharge side to the suction side of the pump, so the pump must spin at a higher RPM to maintain output.

In Fig. 8, a positive displacement pump curve shows the influence of viscosity on slip with a correction chart. With changes in viscosity and pressure, slip correction indicates that flow capacity drops from a high of about 7 GPM to a low of about 3.5 GPM. Once viscosity is over 1000 cPs, slip basically doesn't occur in liquid sanitary pumps. **If slip is not a factor, use the 0 PSI line to determine flow rate.**

Because PD pumps generate flow to transport relatively high viscosity fluids, PD pump selection requires analysis of three key influences on fluid transfer:

The fluid's **dynamic viscosity, density,** and response to **shear.**

> **Fig. 8.** Slip correction accounts for variations in pump performance while factoring fluid viscosity (resistance to flow) and discharge pressure.

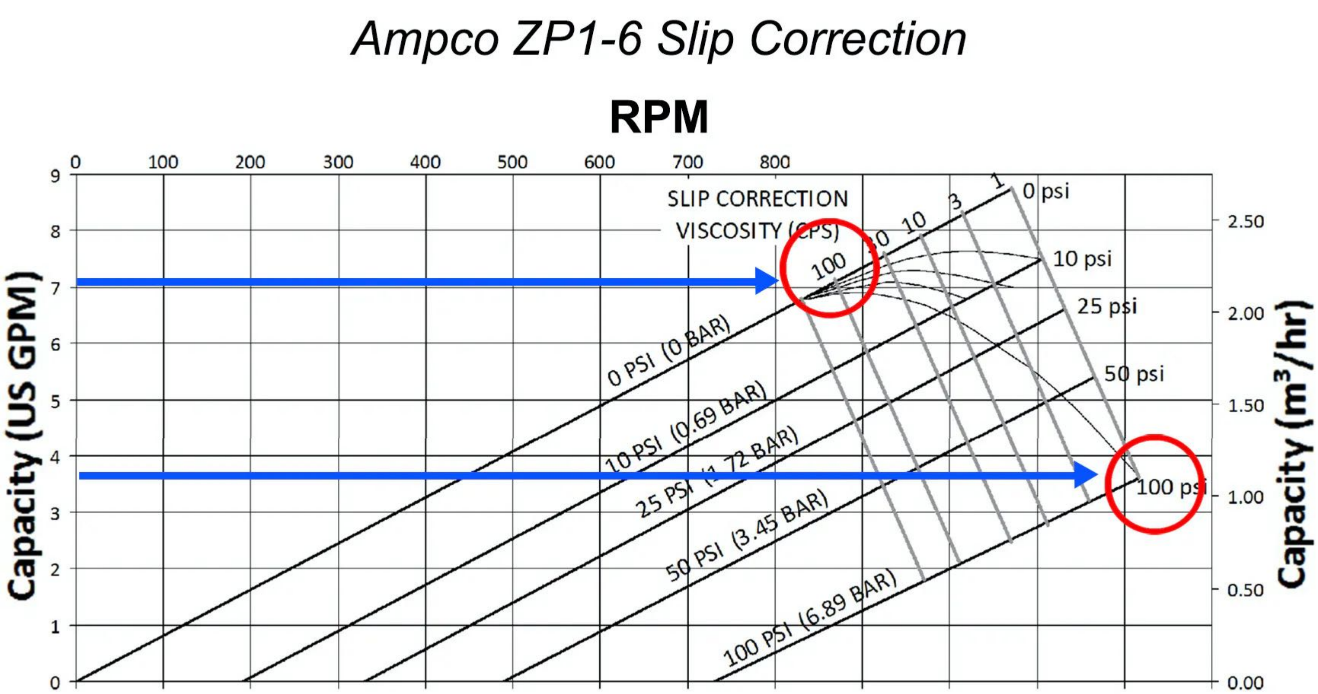


Figure 8

Dynamic viscosity

Dynamic viscosity is a measure of a fluid's resistance to flow. By common sense alone, we can imagine that water is less viscous, or resistant to flow, than corn syrup, so corn syrup has a higher viscosity than water. We measure internal resistance to flow as absolute viscosity (also referred to as dynamic viscosity). It is critical for the viscosity used to be consistent with “in pump” shear conditions, or shear rates of 800 or more s^{-1} (inverse seconds). As the following comparison shows, differences in viscosity vary dramatically by fluid:

- At room temperature, the absolute viscosity of water is about 1 centipoise (cps)
- At room temperature, the absolute viscosity of corn syrup is about 5,000 centipoise (cps)

Density

Density is a measure of a fluid’s weight by volume. Water is less dense than corn syrup, for example, so if you put equal volumes of water and corn syrup side by side, the corn syrup would weigh more than the water. Also, due to the differences in density between water and corn syrup, water would float on top of the corn syrup if combined. The following comparison shows the difference in density between water and corn syrup in kilograms per cubic meter:

- Density of water: 1 g/cm^3 or 997 kg/m^3
- Density of corn syrup: 1.38 g/cm^3 or 1380 kg/m^3

Shear

Shear-sensitive liquids change viscosity when under stress, such as when they are hit by an impeller inside a pump. Some liquids become less viscous with increased force (called shear thinning), while others become more viscous with increased force (called shear thickening).

> **By comparison, Newtonian liquids, such as water, do not change their viscosity, regardless of shear.**

The viscosity of shear-sensitive substances through a process line does change, however. Common shear-sensitive substances include ketchup, shampoos, and polymers; as shear increases during ketchup processing, ketchup’s viscosity decreases.

Continuing with the ketchup processing example, the next section discusses additional important information on pump curves: **work horsepower (WHP), viscous horsepower (VHP), and Net Positive Suction Head required (NPSHr).**

Brake horsepower

When you size a PD pump it will be important to select the correct brake horsepower. **Brake horsepower (BHP)** is the power the pump requires to overcome the discharge pressure. BHP is determined by adding the work horsepower (WHP) and the viscous (VHP) horsepower.

BHP = WHP + VHP

To properly analyze brake horsepower, you must look at work horsepower versus viscous horsepower.

Work horsepower

Work horsepower (WHP) is the horsepower required for the selected PD pump to achieve the desired flow rate considering the anticipated pressure drop from system components. Components like valves, heat exchangers, and filter/strainers, to name a few. WHP is sometimes called external horsepower.

To determine WHP find the intersection of anticipated differential pressure (PSI) and RPM, as shown in Fig. 9. Recall the required RPM was a result of flow required coupled with slip correction, if any.

> **Fig. 9.** Work horsepower (WHP), is the horsepower required to operate a Positive Displacement Pump. As pressure from the discharge side of the pump increases, the pump requires additional horsepower to operate. For example, at 300 RPM and with 150 PSI, the pump requires 6.7 working horsepower.

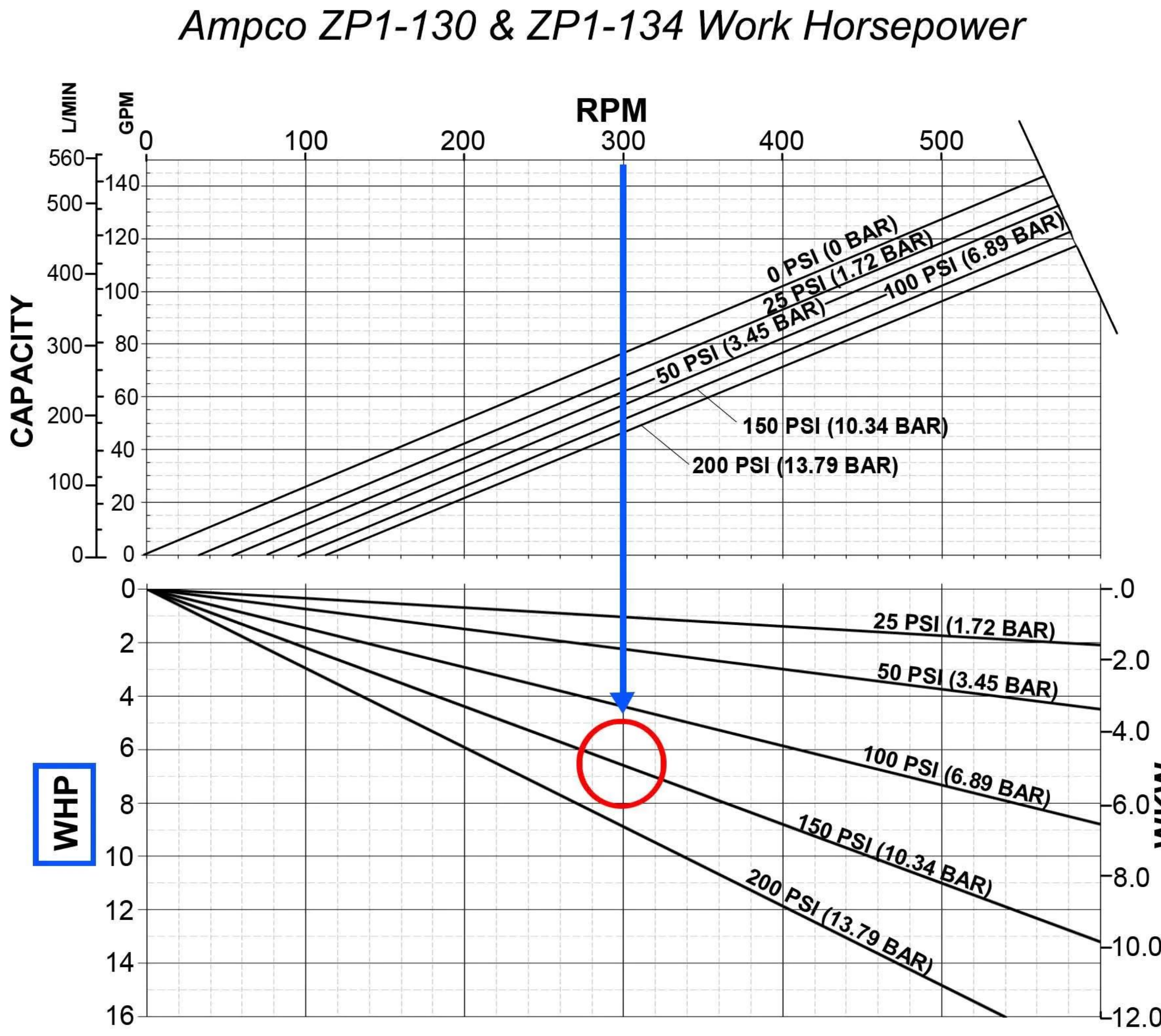


Figure 9

Viscous horsepower

Maintaining pump capacity at various viscosities requires meeting horsepower minimums, as shown in Fig. 10. There is a certain minimum horsepower requirement to force the rotating parts of the pump to turn, considering the viscosity of the fluid in the pump. **VHP is sometimes called internal horsepower**.

To arrive at required horsepower for an application, add WHP and VHP.

- WHP = 6.7
- VHP = 4
- Required HP is 6.7 + 4 = 10.7

> **Fig. 10.** Viscous Horsepower (VHP) is the power needed to turn rotating parts of the pump against the fluid inside the pump. At 300 RPM and a viscosity of 500 CPS, a pump requires 4 VHP.

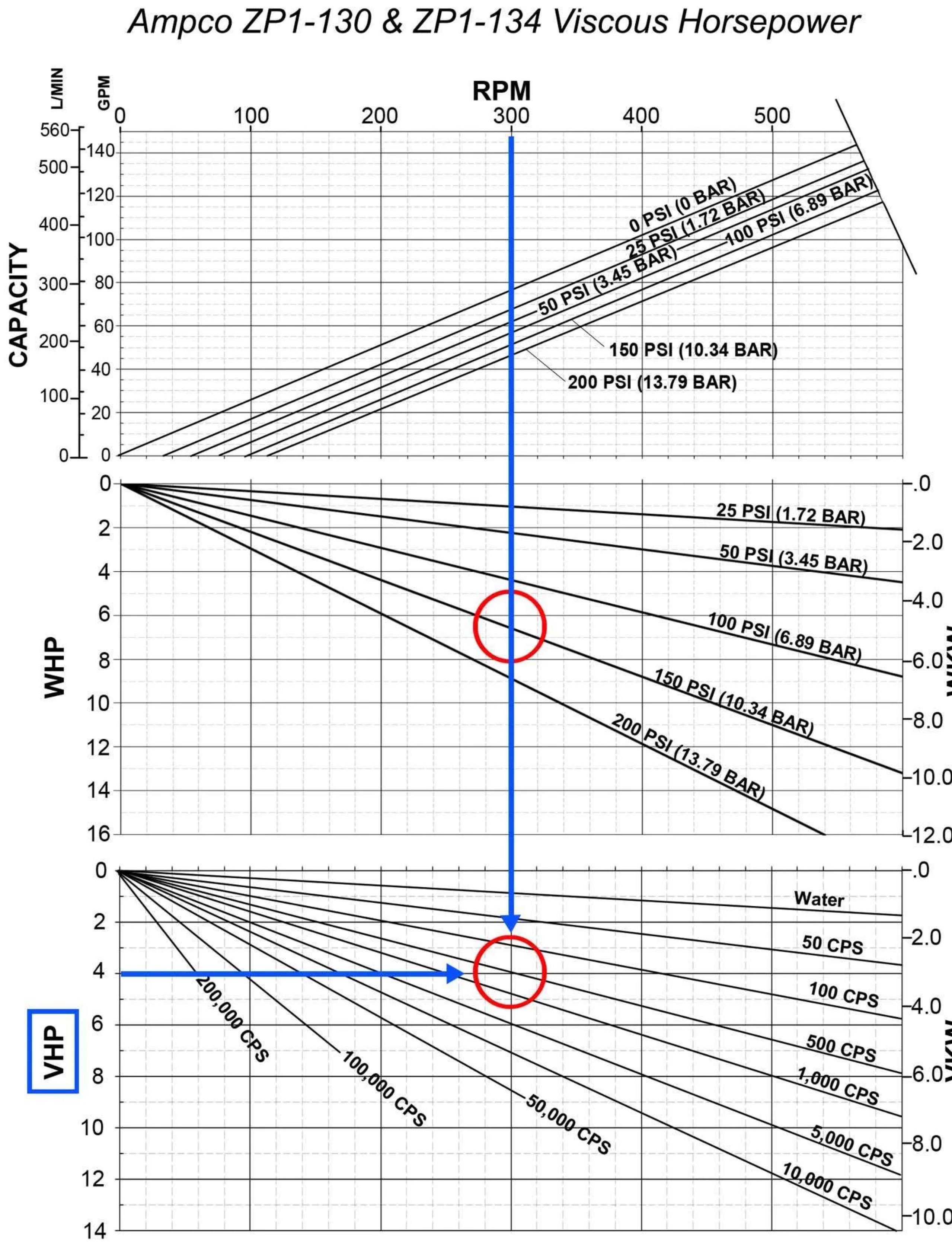


Figure 10

NEXT STEPS

As you processor, you need a pump that transfers product safely and efficiently from point A to point B. But with such a large variety of pumps, motors, and applications, picking the right pump can be difficult.**That's where we come in!**

CSI is known as the experts in the specification, sizing, and supplying of pumping technology for hygienic industry processes. Speak with our knowledgeable pump team today and be confident in your next pump purchase!

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A Guide to Choosing the Right Pump for Hygienic Applications

This guide is intended for engineers, production managers, or anyone concerned with proper pump selection for pharmaceutical, biotechnology, and other ultra-clean applications.

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