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Let's Solve Water

WHITE PAPER
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White Paper Series: Part 2 – Horsepower on the pump curve

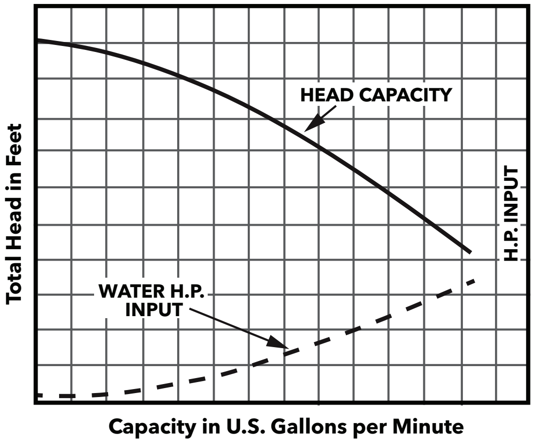
Presented by: Xylem Applied Water Systems

Now that the head capacity relationship along the X and Y axes of the pump curve has been established in Part 1 of this series, the pump curve can be used to determine the amount of horsepower required to meet the head and capacity requirements for the job.

Horsepower is a unit of power equal to 550 foot pounds per second or 746 watts. Water horsepower is the minimum power required for a pump to move water throughout a given system, or the power that the pump would require if it were 100 percent efficient.

Determining water horsepower

When work (or head in foot-pounds per pound) is combined with the flow rate (measured in gallons per minute (GPM)), the result is the conversion for horsepower. This energy imparted to water by the pump is called water horsepower (WHP).



Water Horsepower Input Curve

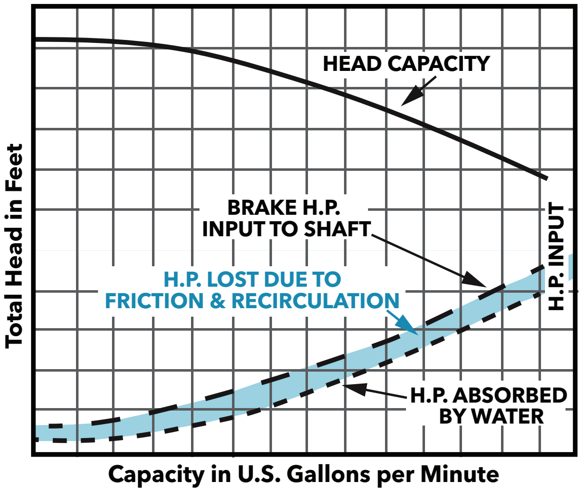
Water horsepower is zero at no capacity and increases with increasing flow, representing an important characteristic of the centrifugal pump – power requirements generally increase with flow, even though head decreases.

Water horsepower also increases with fluid density, even though the head capacity curve is not changed. This is because at any fixed GPM point, more mass (more pounds per minute of fluid) is being pumped at the higher fluid density. If a fluid with twice the density of water were pumped, the required water horsepower would be doubled. The effect of fluid density must be taken into account when evaluating horsepower requirements for fluids other than water.

Brake horsepower

No pump can convert all of its mechanical power into water power. This is due to friction losses in the bearings, water friction itself and recirculation within the pump. To compensate for those losses, horsepower going into the pump (at the pump shaft) must be greater than the water horsepower leaving the pump. These additional power losses define the total brake horsepower requirement (BHP) at the pump shaft. Brake horsepower is the actual horsepower delivered to the pump shaft. The formula for figuring brake horsepower is:

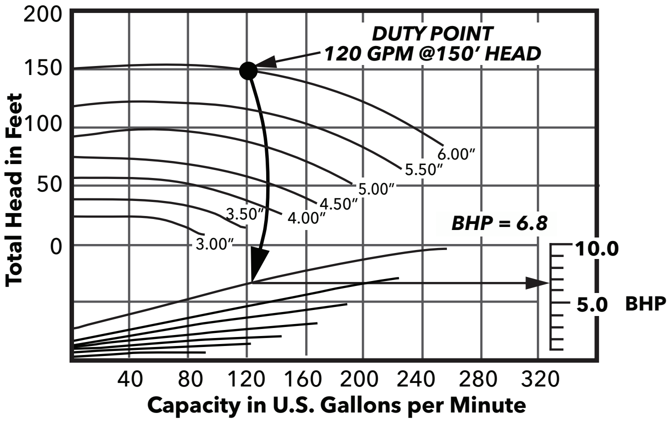
$$\text{Brake HP} = \frac{\text{GPM} \times \text{Feet Head} \times \text{Specific Gravity}}{3960 \times \text{Pump Efficiency}}$$



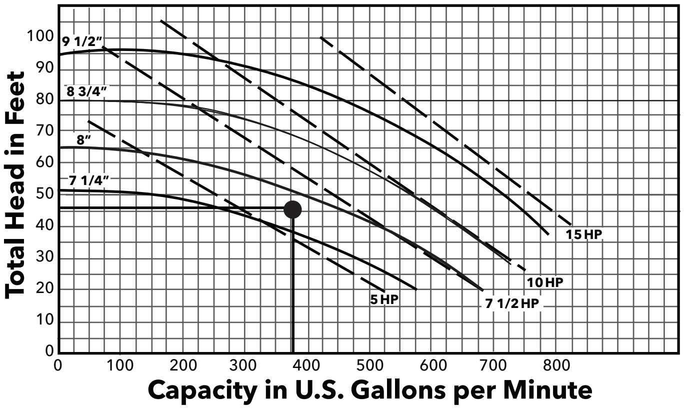
Total BHP Requirement Curve

The head capacity curve will give information on the brake horsepower required to operate a pump at a given point on the curve. The brake horsepower curves run across the bottom of the head capacity curve usually sloping upward from left to right. These lines correspond to the curves above them (the top head capacity curve corresponds to the top BHP line and so on). Comparable to the head capacity curve, there is a brake horsepower curve for each impeller trim.

In the example below, the design (or duty) point is at 120 GPM and 150 feet of head; the corresponding brake horsepower is 6.8 BHP.



Horsepower can also be plotted as lines of constant horsepower as shown below. Horsepower is plotted across the head capacity curves as dashed lines at a downward angle. In the example below, the design point is at 375 GPM and 45 feet of head; the corresponding brake horsepower falls between 5 and 7.5 and is approximately 6.5 BHP.

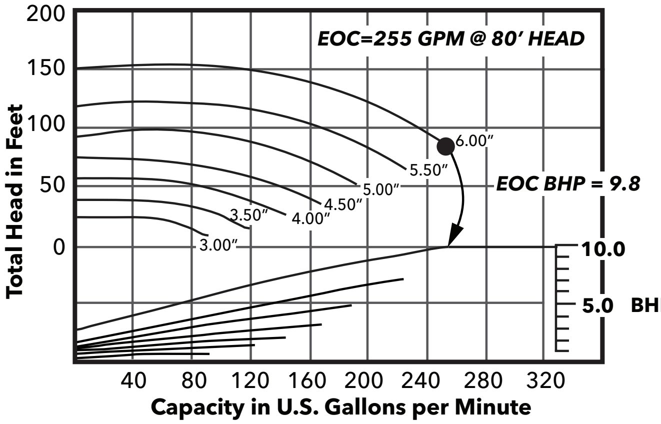


End of curve horsepower

When sizing the motor for any application, an important consideration is whether the pump will ever be required to operate at a flow rate higher than the design point.

If, for example, the pump was allowed to operate at the end of the head capacity curve, the actual horsepower requirement may exceed the design point selected motor horsepower and overload the motor. As previously noted, power requirements generally increase with flow, so the motor will draw more current because the pump is applying more horsepower to the fluid. For this reason, it is common practice to size the motor not for the design point, but for the end of the curve or maximum horsepower requirements.

In the example below, a 7.5 HP motor would adequately power the pump at a design point of 120 GPM at 150 feet; however, looking at the end of the curve, brake horsepower requirements call for a 10 HP motor.



Affinity Laws

It's also important to keep in mind the Affinity Laws that are associated with the rotational speed (RPM) and impeller diameter of a centrifugal pump. Affinity Laws are mathematic relationships that allow for the estimation of changes in pump performance as a result of a change in one of the basic pump parameters. These principles assume the operating points are at the same efficiency. If either the speed or impeller diameter of a pump changes, you can approximate the resulting performance change using the following relationships:

Pump Affinity Laws	Capacity	Head	BHP
Impeller Diameter Change (Speed Constant)	$Q_2=D_2/D_1\mathrm{x}Q_1$	$H_2=(D_2/D_1)^2\mathrm{x}\ H_1$	$P_2=(D_2/D_1)^3\mathrm{x}P_1$
Speed Change (Impeller Diameter Constant)	$Q_2=R_2/R_1\mathrm{x}Q_1$	$H_2=(R_2/R_1)^2\mathrm{x}\ H_1$	$P_2=(R_2/R_1)^3\mathrm{x}P_1$

Q=Capacity H=Head P=BHP D=Impeller Diameter R=Speed

Note that brake horsepower varies directly as the cube of the RPM or impeller diameter ratio. If RPM or the impeller diameter of an existing pump is increased, the motor's rated horsepower should be verified to prevent overloading.

Knowing how to determine horsepower on the head capacity curve will assist in selecting the best pump for the job or determining the pump's performance in a specific situation. Pumps that operate at higher efficiencies will save horsepower and use less electricity, reducing operating costs.