Centrifugal Pump Selection
Part 2: Horsepower, Efficiency, & NPSH

In part 1 of this GATEKEEPER series, we discussed how centrifugal pumps work, pump selection criteria as well as the four components of total head (TH), static head, friction head, pressure head, and velocity head. Pump capacity, total head (TH) of the system, horsepower, efficiency and Net Positive Suction Head (NPSH) are all needed in order to accurately size the pump.

In part 2, horsepower, efficiency and NPSH will be discussed which will lead to a final centrifugal pump selection.

Determining Which Pumps to Consider

Some manufacturers produce charts showing multiple pumps on one chart (See Figure 1). Manufacturers can also provide pump curves for each pump (See Figure 2). These summary charts are useful for narrowing the selection.

Pump Speed

The available motor speeds for standard 60-cycle current AC electric motors are based on Equation 1. For a 50-cycle current the equation is revised to Equation 2. Pump curves are typically provided for different motor speeds. A pump curve at a given speed can also be converted for different motor speeds via affinity rules.

Impeller Size

Centrifugal pumps have the capability to operate over an extended range of head and flow by varying the impeller diameter. The pump curve will usually show curves for several impeller diameters and it is usually possible to machine the impeller to match system requirements.

Horsepower

Horsepower is the amount of energy that must be supplied to operate the pump. The water horsepower (WHP) refers to the output of the pump handling the liquid of a given specific gravity, with a given flow (Q) and TH. WHP is determined using Equation 3.

Brake horsepower (BHP) is the actual amount of power that must be supplied to the pump to obtain a particular flow and head. BHP is usually used to select an appropriately sized motor. Equation 4 is used to determine BHP.

Efficiency

Pump curves show pump efficiency. A pump operating near peak efficiency should be selected.

Vendor Pump Curves

Figure 2 is a typical pump curve. Superimposed on the pump curves in Figure 2 is an example of a system curve.

The operating point of the pump is the intersection of the pump curve and the systems curve for the design flowrate. Note that in Figure 2, the intersection occurs at an impeller diameter of 19.5 inches. Assuming that this impeller size is selected, then the BHP required and NPSH required can be read from the curve.

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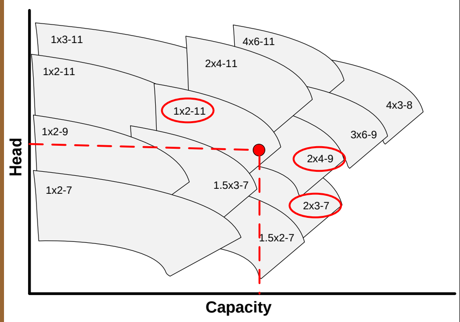

Figure 1: Pump Summary Diagram

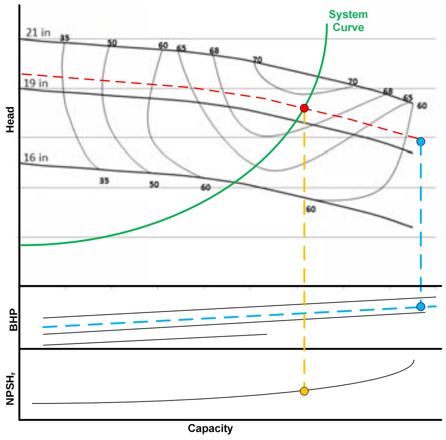

Figure 2: Pump Curves

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General Guidelines for Accurately Sizing a Centrifugal Pump:

1. Determine total head and capacity of the system. Generate the System Curve
2. Use the pump curves to determine Efficiency, BHP and NPSHr.
3. If practical, choose a motor size capable of delivering more flow than required.

Equation 1:

$$rpm = \frac{7200}{N}$$

Equation 2:

$$rpm = \frac{6000}{N}$$

N (# of Poles)	rpm
2	3600
4	1800
6	1200
8	900
10	720
12	600

Equation 3:

$$WHP = \frac{Q \times H \times SG}{3960}$$

Q = Flow Rate in gpm
H = TH in feet

$$WHP = \frac{Q \times H \times SG}{8.82}$$

Q = Flow Rate in ft³/s
H = TH in feet

Equation 4:

$$BHP = \frac{WHP}{\eta}$$

η = pump efficiency

Equation 5:

$$NPSH_a = P \pm H - H_f - H_{vp}$$

Considerations when reading the pump curves include:

- Impeller diameter can be any of the standard sizes shown on the chart or the impeller can be machined down to the required impeller diameter.
- It is good practice to choose a motor size capable of delivering significantly more flow than the design point to account for potentially higher loads during startup, shutdown or upset conditions and to provide margin for debottlenecking.
- If possible, choose the horsepower that will give you enough power to run the pump at the end of its curve as shown in Figure 2.
- Growing requirements should be a consideration when selecting a pump. Is the design rate suitable for the life of the pump, or will there be an increase or decrease in flow or head in the future? If there will be an increase in flow or head, when will this take place? Will a larger pump or a larger impeller be needed now, or could a smaller pump work for now with a replacement needed later in life?

NPSH and Cavitation

Cavitation is a phenomenon that occurs when vapor bubbles form and move along the vane of an impeller. As the vapor bubbles move along the vanes the pressure around the bubble increases. When the pressure inside the bubble is less than the pressure outside, the bubble collapses or implodes. As hundreds of these bubbles implode, physical removal of material from the impeller and excessive vibration of the pump causing failures of seals and bearings can occur. Pump performance often drops off its expected performance curve, producing lower head and flow.

NPSH must be examined when using centrifugal pumps to predict the possibility of cavitation. There are 2 aspects to consider:

- NPSH available ($NPSH_a$) is the suction head present at the pump suction over and above the vapor pressure of the liquid. Equation 5 is used to determine the $NPSH_a$.
  - P is the absolute pressure on the surface of the liquid in the suction vessel in feet.
  - H is the elevation distance from the surface of the liquid in the supply vessel to the centerline of the pump impeller in feet.
  - H_f is the friction loss in the suction line in feet.
  - H_{vp} is the vapor pressure of the liquid at the pumping temperature in feet.
- NPSH required ($NPSH_r$) is the suction head required at the impeller centerline over and above the vapor pressure of the liquid. The pump curve should provide the $NPSH_r$ for the selected impeller diameter. See the orange line in Figure 2.
- $NPSH_a$ should be greater than $NPSH_r$.

To be conservative, $NPSH_a$ should be calculated based on the lowest liquid level in the supply vessel (minimum static head or maximum static lift) with the highest friction losses in the suction system and at the highest expected liquid temperature.

Minimum Flow

Large pumps often have a significantly high required minimum flow provided by the manufacturer. All pumps will overheat if deadheaded (zero flow). Provision of minimum flow is an important aspect of the pump system design.

Oversizing Pumps

Engineers are often conservative in their estimates of TH and flow requirements. Oversized pumps can lead to higher capital costs and wasted energy (higher operating costs). This should be taken into consideration when choosing a pump.