Pioneering for You

Getting the Most Out of Your Pumps

Reading and Understanding the Centrifugal Pump Performance Curves

To optimize pump performance, understanding the centrifugal pump performance curve is essential. These curves help identify and select the right centrifugal pump by visually representing the pump's ability and efficiency to move water and the energy required to do so.

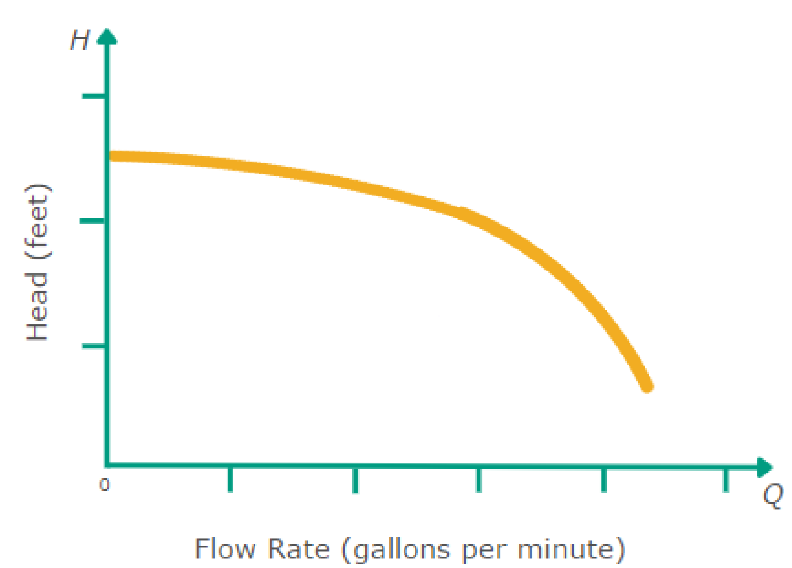
The pump performance curves for centrifugal pumps include:

- Head and Flow Curve
- Efficiency Curve
- Power (Brake Horsepower) Curve
- Net Positive Suction Head Required Curve

Head and Flow Curve

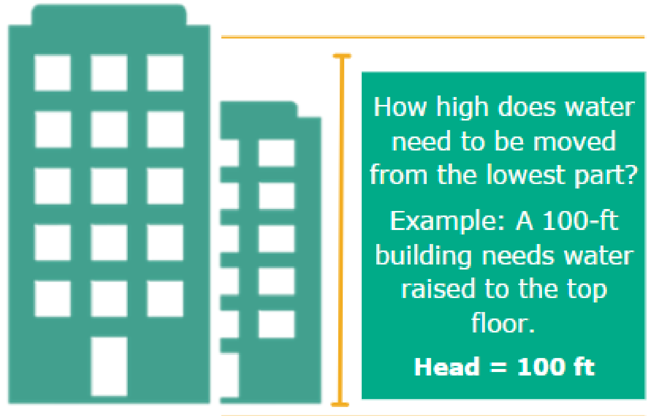
The Head and Flow Curve is the most used curve to describe pump performance illustrating the relationship between flow rate (Q, x-axis) and head (H, y-axis) at a constant pump speed for a centrifugal pump. As flow decreases, head increases, and as flow rate increases, head decreases, therefore they are relational, showing an inverse relationship (Image 1).

Image 1: Head and Flow Curve



Head

Head evaluates a pump's capacity to do a job. Head is the amount of energy the pump needs to transfer water to its intended destination. It is measured in feet and represents the height to which a pump can raise water with no resistance to flow.



Head is different from the term Total Head (TH). While head is the height at which a pump can raise water and is graphically shown in a Pump Performance Curve, TH represents pressure losses due to elevation and friction pressure within a pumping system and is represented in the System Curve.

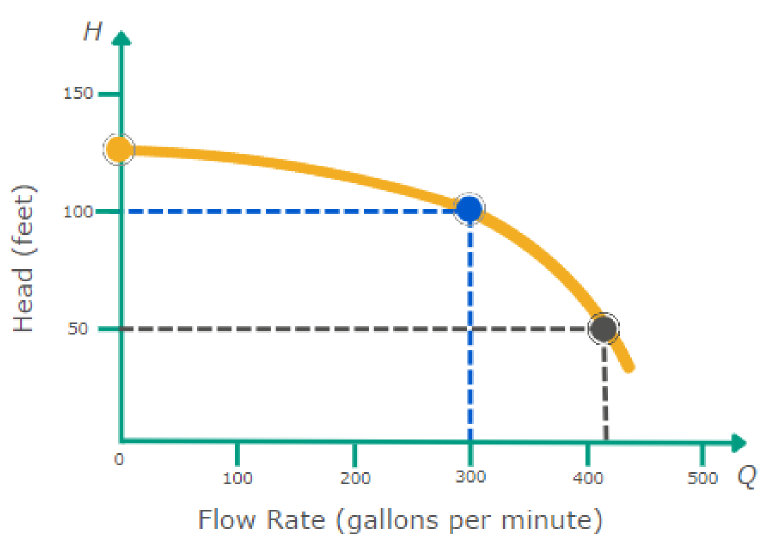
Head remains constant regardless of a fluid's characteristics. Head is fluid-independent, whether the fluid is water or heavy sludge.

Pressure, measured in pounds per square inch (psi), varies based on a fluid's specific gravity, viscosity, and temperature. Measuring head in feet makes the pump curve applicable to most fluid types. There is a direct relationship between head and pressure: 1 psi is equivalent to 2.31 feet of head.

Flow Rate

Flow rate (x-axis) indicates the volume of water a pump can move over time at a given pressure. For example (Image 2), a pump can move water 100 feet at 300 gallons per minute (gpm, blue point). As head decreases, flow increases. At 50 ft, water flow increases to 410 gpm (black point).

Image 2: Head and Flow Curve



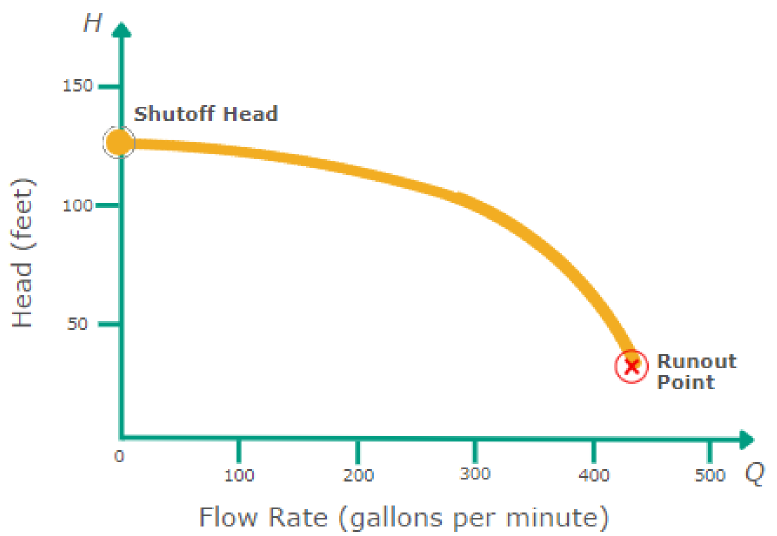
Shutoff Head & Runout Point
A head and flow curve starts at zero flow, or shutoff head (Image 3, yellow point), and descends to the pump's maximum flow it can produce, or runout point (Image 3, red point).

For example, at 0 gpm the head (shutoff head) is 125 feet, the highest pressure the pump can manage. With a closed "shutoff" valve, the pump operates at a high pressure without waterflow. Opening the valve allows water to flow. As water flow increases, generated pressure follows the curve and head drops until the pump reaches its "runout point".

Operating at shutoff head (or deadhead) for extended periods forces the pump to circulate water without an outlet, causing overheating and potential damage. For fire pumps, shutoff head is called "churn pressure" because the water churns inside the pump without an outlet, heating the pump.

Operating on the opposite end of the curve near or at runout, the high-water flow causes reduced efficiency, and increased turbulence and vibration which can quickly damage the pump. At or near the runout point, the pump can sustain damage due to an increased Net Positive Suction Head Required (NPSHr), which, if unmet, can cause cavitation. Additionally, motor damage can occur from high heat, as the farther out on the pump curve the flow is, the more amps the motor draws, generating heat.

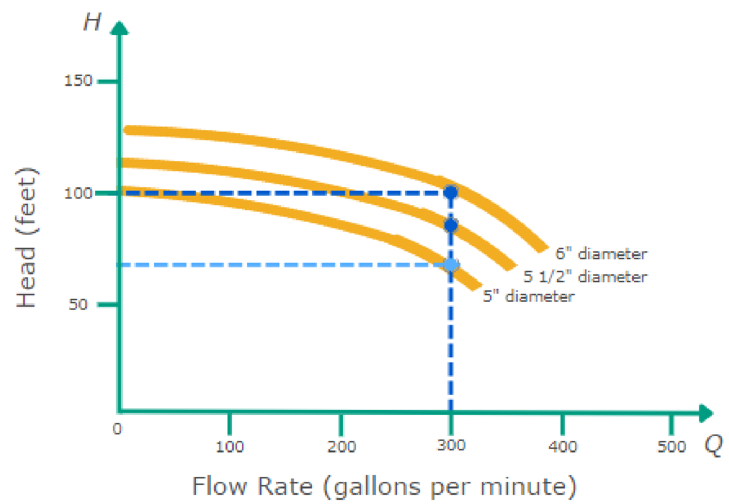
Image 3: Head and Flow Curve



Impeller Diameters
Impeller diameter (size) is an integral part of selecting a radial-type centrifugal pump. Curves for different impeller diameters show how changes in impeller size affect pump performance. These curves are useful when modifying the pump's performance, such as adjusting head, flow, or power consumption. To learn more about the relationship of impeller diameter and pump performance, refer to the "Affinity Rules" (formerly known as the Affinity Laws).

Smaller impeller diameters lower the shutoff head and runout point, affecting head and flow. For instance (Image 4), the 6" impeller has a shutoff head of 125 feet, while a smaller 5" impeller will have a lower shutoff head of 100 feet. At 300 gpm water flow, the 6” impeller provides 100 feet of head, while the 5” impeller provides 60 feet of head.

Image 4: Head & Flow Curve with Multiple Impeller Sizes



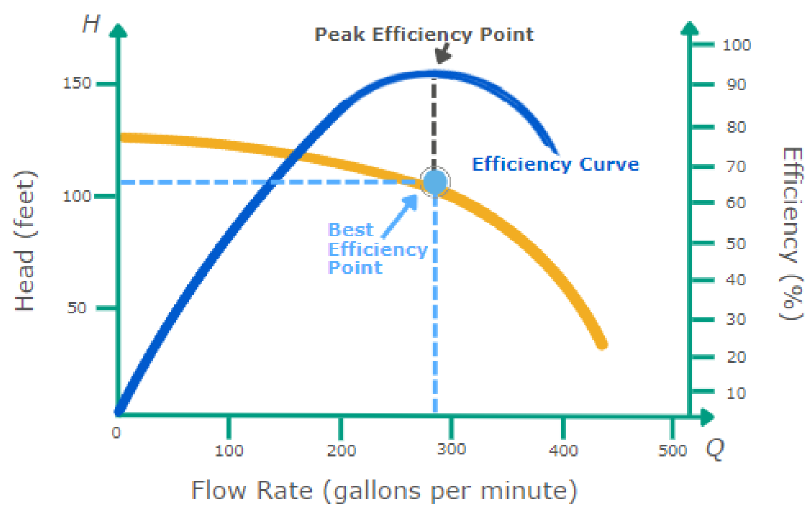
Efficiency Curve

The pump’s Efficiency Curve represents the pump’s efficiency (η) at various flow rates. It indicates how efficient the pump utilizes the energy provided by an outside source and transfers that energy to the water.

Best Efficiency Point

The flow rate where efficiency is at a maximum is called the pump’s Best Efficiency Point (BEP, Image 5, blue point). Operating the pump near this point promotes a smooth flow of water with low vibration and noise and can help minimize power costs and extend the pump’s life.

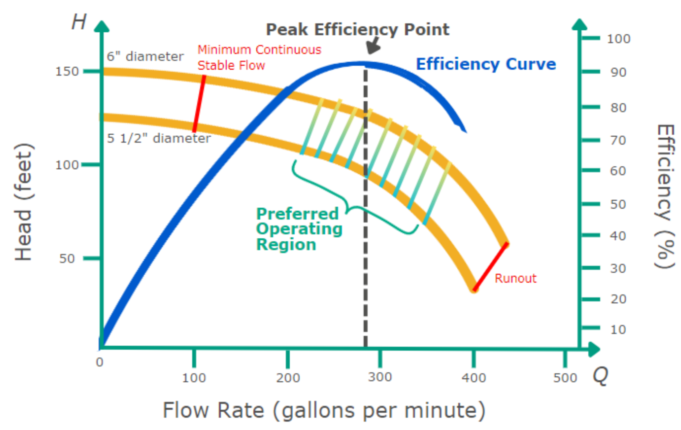
Image 5: Efficiency Curve



Preferred Operating Region

Operating too far right or left of BEP reduces pump performance and can cause damage. To prevent this, manufacturers identify a "Preferred Operating Region (POR)" on the pump chart. The Hydraulic Institute typically defines the POR as the flow rates between 70 to 120 percent of the BEP flow rate. For example, with a BEP flow rate of 290 gpm the POR can be determined to range from 203 (70% of BEP) to 348 gpm (120% of BEP) (Image 6, green region).

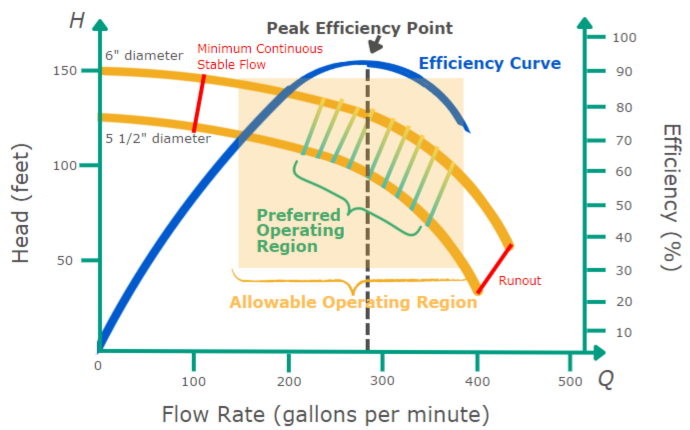
Image 6: Preferred Operating Region (POR)



Allowable Operating Region

The Allowable Operating Region (AOR) is a broader range than the POR (Image 7, yellow region). Unlike the POR, AOR has no defined standard and is determined by the pump manufacturer through testing. It identifies the flow range where the pump can operate continuously without significantly affecting performance or lifespan. Operating outside of the AOR is not recommended and may void the manufacturer's warranty. When the pump operates outside the AOR, efficiency and pump performance decrease, and vibrations can cause wear on bearings, seals, and motor shafts, reducing the pump's life and potentially causing damage. To learn more about operating the pump outside of the AOR, please read "The Dangers of Operating Too Far Right or Left of BEP."

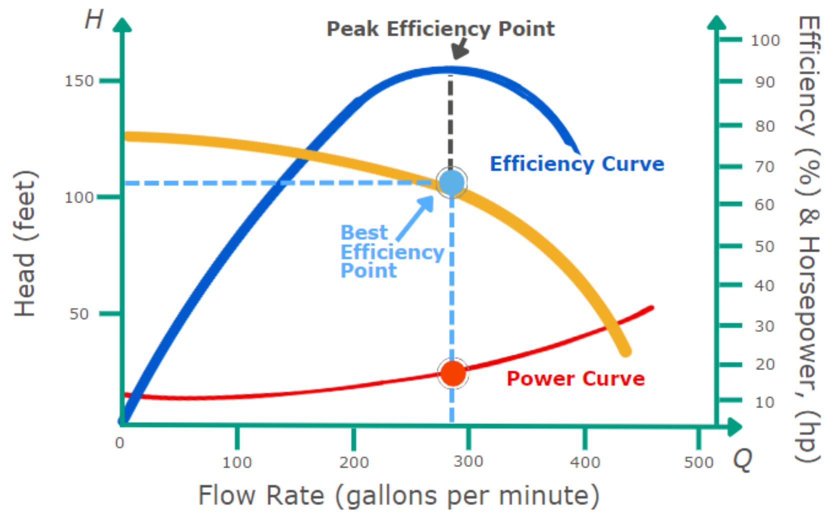
Image 7: Allowed Operating Region (AOR)



Power (Brake Horsepower) Curve

The Power, or Brake Horsepower (BHp), Curve represents the horsepower required from the motor to drive the pump to deliver a given flow rate and head (Image 8, red curve). It is represented on a y-axis, in units of horsepower (hp). As water flow increases, the pump's power consumption also increases. A power curve helps with proper motor sizing to ensure the correct motor size based on the maximum power needs. The pump curve can be shown on the same chart (as in Image 8), or on a separate one depending on the values placed on the y-axis.

Image 8: Power Curve



Net Positive Suction Head Required

The Net Positive Suction Head required (NPSHr) Curve, expressed in feet, shows the minimum required pressure at the pump's inlet to avoid cavitation at a given flow rate. Cavitation reduces performance, causes noise, and leads to erosion damage due to the formation of vapor cavities when the pressure in the pump drops below the liquid's vapor pressure. These vapor cavities implode back to liquid when they reach a higher-pressure area at the end of the impeller's vanes, causing noise and erosion damage.

The NPSHr curve can be shown on the same pump performance chart or as a separate chart (as in Image 9) depending on the y-axis values needed. To avoid performance reduction and cavitation, the NPSH available (NPSHa) at the pump's suction port must be greater than the NPSHr in the pumping system.

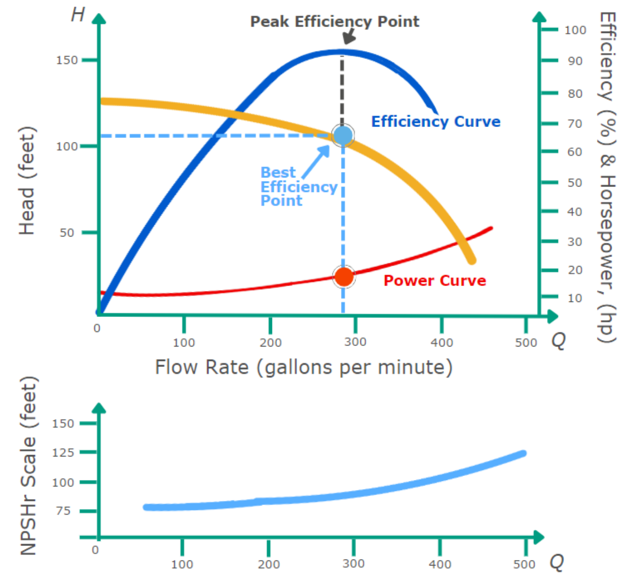


Image 9: Net Positive Suction Head required (NPSHr) Curve

Conclusion

Reading, understanding, and interpreting centrifugal pump performance curves is crucial for selecting and maintaining the right pump. These curves provide valuable insights into the pump's performance under various flow and head conditions, efficiency, and operational limits, allowing for informed decision-making and optimal system design. By mastering the key components of pump performance curves, such as the head and flow curve, efficiency curve, power curve, and NSPHr curve, you can ensure your pump operates efficiently and reliably, minimizing the risk of damage and maximizing the lifespan of the pump.

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Wilo USA, a leading provider of innovative pump solutions, integrates sustainability into its core operations through its Creating, Caring, and Connecting approach, ensuring efficiency, reliability, and environmental stewardship across industries.

Wilo offers a wide variety of intelligent, centrifugal pumps and systems to make our users' everyday lives more pleasant. Our solutions are used in heating, air conditioning, cooling, and water supply applications, as well as for drainage and sewage. To learn more about Wilo USA's pump solutions and products, visit http://wilo-usa.com.

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