Beyond the Best Efficiency Point:

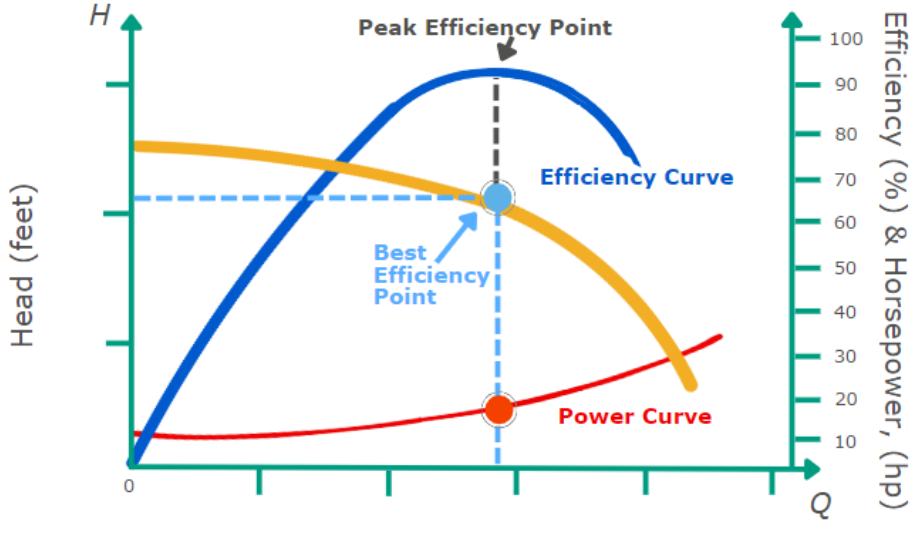
The Dangers of Operating Too Far Right or Left of BEP

The Best Efficiency Point (BEP) is a critical value in centrifugal pump performance curves, representing the flow rate at which a pump operates at its peak efficiency. It also marks the most stable section of the pump curve for optimal pump performance. For centrifugal pumps, operating too far right or left of BEP can lead to significant mechanical issues, decreased efficiency, and increased life cycle costs. Understanding the dangers beyond the BEP is essential for maintaining optimal pump performance and ensuring the longevity of the pump.

Understanding the BEP in centrifugal pump performance curves

The BEP on a pump curve represents the point where the pump operates most efficiently, achieving the best balance between flow rate, head (pressure), and energy consumption (Image 1). At this point on the pump curve, the centrifugal pump delivers water with minimal energy loss and wear on its components. The impeller experiences minimal radial force, promoting smooth operation with low vibration and noise. Operating at or near BEP is crucial for maximizing efficiency and cost-effectiveness in any pumping system.

Image 1: Centrifugal Pump Performance Curves



Operating on either side of BEP

While a pump curve shows the various flow rates and pressures a pump can operate at, not all points on the curve are ideal for operation. The BEP identifies a point of highest efficiency, but pumps often operate at flows higher or lower than BEP due to system demands or improper pump selection.

Operating pumps at extremes-too far right or left of BEP- poses challenges. As flow deviates from BEP, the hydraulic pressure within the centrifugal pump becomes increasingly unbalanced, applying radial thrust to the impeller and shaft. The unbalanced radial and axial loads on the impeller cause shaft deflection, which decreases mechanical seals, bearings, shaft, and shaft sleeve working life and reduces the critical speed of the shaft. Operating too far right or left of BEP amplifies the radial thrust forces (Image 2), leading to increased shaft stresses, potential bearing problems, and heighted vibrations.

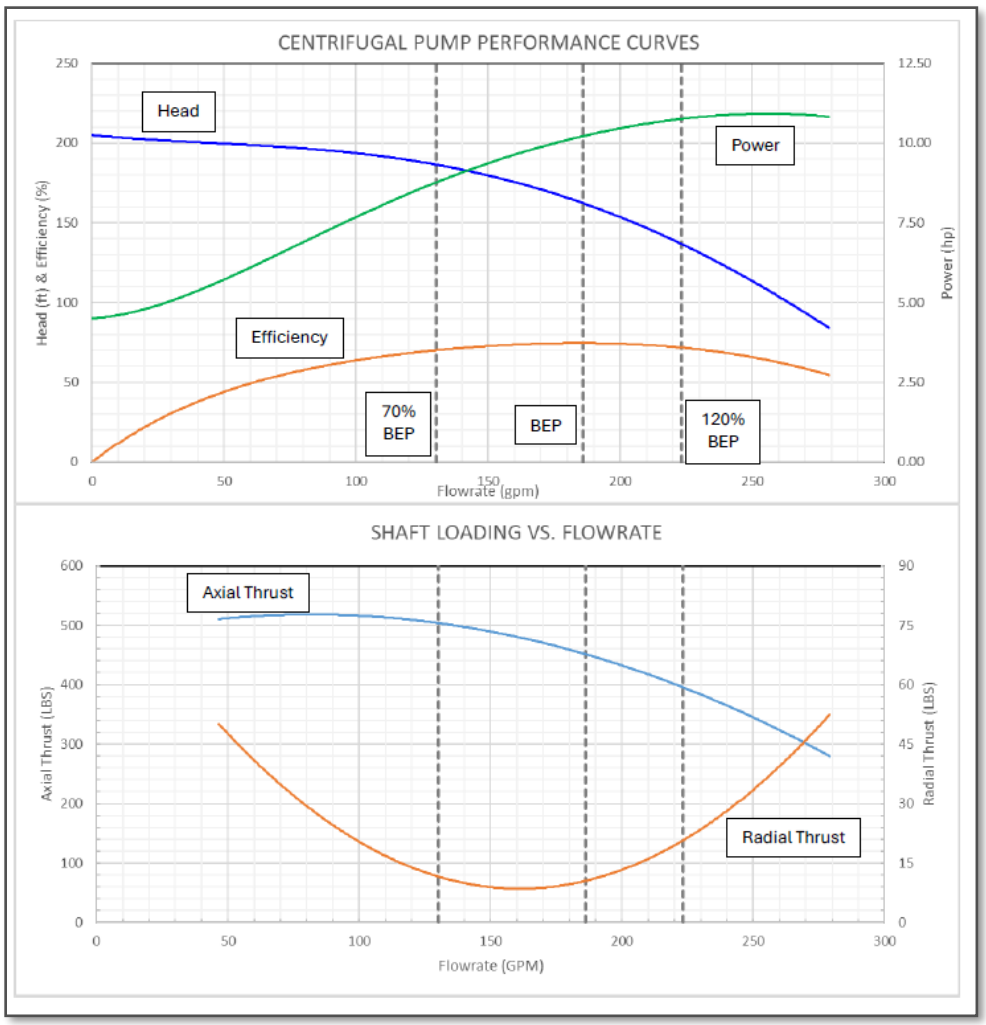
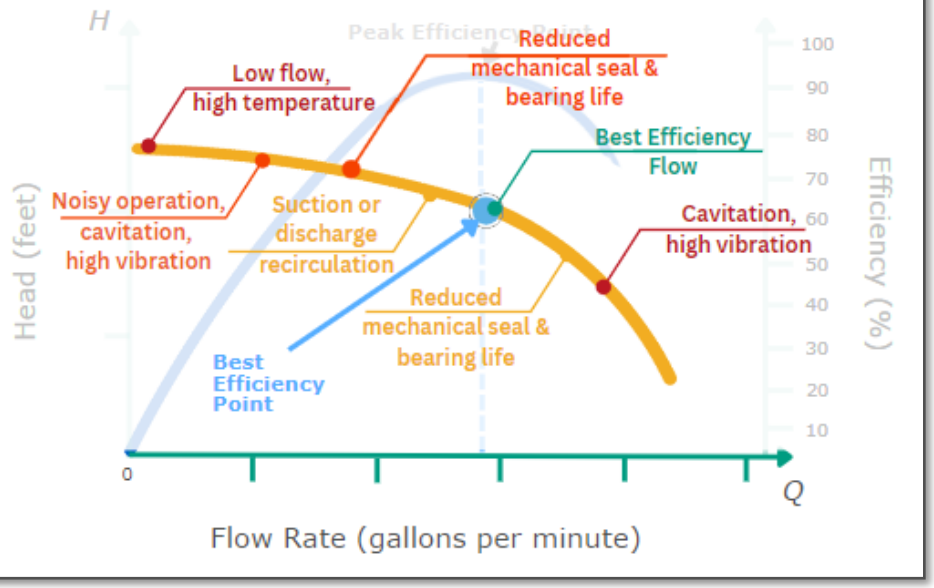


Image 2: *Advanced Computational Fluid Dynamics (CFD) simulation on a typical centrifugal pump showing distribution of shaft loads across the operating range of a pump. Note the general increase in loads outside of the preferred operating region (POR). Image courtesy of Wilo USA Engineering.*

Operating too far right or left of BEP can have serious consequences on the impeller, casing, motor shaft, mechanical seals, and bearings (Image 3).

Image 3: Consequences of Operating Either Side of BEP



Operating Too Far Right of BEP

Operating to the right of BEP means the pump is running at a higher flow rate than optimal or that it is designed for. This can happen if the pump is undersized for the application or if here is a sudden demand increase in the system. Operating too far right of BEP can lead to:

- **High velocity and turbulence:** High flow rates cause excessive velocity and turbulence, leading to increased wear on the impeller and casing.
- **Increased discharge:** Higher discharge rates can cause noise and vibrations that put additional strain on the motor shaft and other components.
- **Motor overload:** The pump may draw more power than it is designed for, overheating and potentially damaging the motor.
- **Increased maintenance costs:** High flow induced vibration can damage mechanical seals and bearings, raising maintenance costs and increasing the risk of pump failure.
- **Reduced lifespan:** Consistently operating at high flow rates shortens the pump's life span due to excessive wear and tear.
- **Cavitation:** At higher flow rates Net Positive Suction Head required (NPSHr) increases exponentially, which may exceed the Net Positive Suction Head available (NPSHa), leading to cavitation. This phenomenon, where vapor bubbles form and collapse due to pressure changes, can cause impeller erosion, excessive vibration, increased strain on shaft and bearing, loss of efficiency, and potential component or pump failure.
- **Radial and axial thrust:** High flow rates can increase radial and axial thrust on the impeller, leading to excessive stress on the bearings and shaft. This can result in higher maintenance costs and premature failure of these components.

Operating Too Far Left of BEP

Pumps operating to the left of BEP means the pump is running at a lower flow rate than designed. This reduced flow rate can result from system resistance, blockages, or an oversized pump. The low flow rate results in pressure build up in the pump, leading to serious consequences of operating:

- **Internal circulation of small solids or abrasives**: Low flow and internal recirculation can cause small solids or abrasives to damage the casing, impeller, motor shaft, and wearing rings through friction and erosion.
- **Increased vibration and noise:** Low flow creates a mismatch of flow in the impeller and vanes of the impeller, forming swirls and eddies. These swirls shake the rotor assembly leading to leading to excessive vibration and noise, which are disruptive and can be an indicator of other issues.
- **Seal and bearing damage:** Unsteady water dynamics at low flow rates causes vibration and heat which can cause damage to seals and bearings.
- **Suction or discharge recirculation:** Improper flow through the pump causes recirculation of water at the pump's suction and discharge point, leading to rotor face instability and premature bearing and mechanical seal failures.
- **Discharge restriction:** Restricted discharge flow causes water to recirculate, creating a low-pressure area that can lead to low flow cavitation.
- **Risk of cavitation:** Low flow rates can cause cavitation, where vapor bubble form and collapse, damaging the impeller and other pump components.
- **Overheating:** Reduced flow can lead to overheating of the pump, as the fluid may not be moving through the system quickly enough to dissipate heat. This can lead to premature wear and potential mechanical failure. Low flow can also reduce pressure, or create a vacuum, in the casing, lowering the temperature water will boil. Water may not be able to go anywhere, causing the pressure in the casing to build up, water to boil at a lower boiling points, and overheat, possibly damaging the pump.
- **Increased energy consumption:** Low flow rates pumps perform inefficiently, leading to higher energy usage and operational costs.
- **Radial and axial thrust:** High flow rates can also increase radial and axial thrust, causing uneven loading on the impeller and bearings, which can result in higher maintenance costs and premature failure of these components.

Identifying deviations from BEP

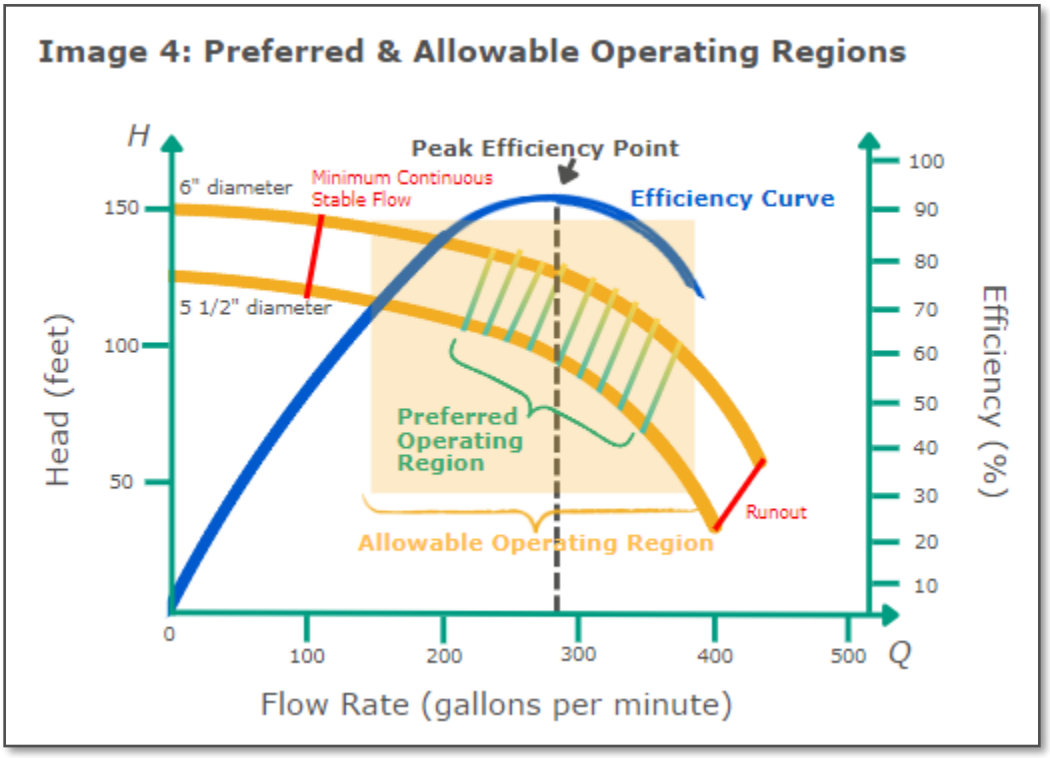
Recognizing when a pump is operating away from BEP is crucial for maintaining optimal performance and preventing damage. Here are key indicates and tools to identify deviations from BEP.

- **Performance changes:** Monitor for shifts in flow rate, pressure, and energy consumption. Deviations from expected performance metrics can be a sign the pump is not operating at or near BEP.
- **Visual and auditory indicators**: Look and listen for unusual vibrations, noise, wear, or leaks. These can be early signs of operating too far from BEP.
- **Monitoring Tools:** Utilize flow meters, pressure gauges, and vibration sensors to continuously track pump performance and detect deviations from BEP in real-time.

Maintaining operation near BEP

To maintain optimal performance, the Hydraulic Institute defines a "Preferred Operating Region" (POR), while manufacturers identify an "Allowable Operating Region" (AOR) through testing for centrifugal pumps (Image 3). The Hydraulic Institute states the POR "is a range of rates of flow greater than or less than the BEP within which the hydraulic efficiency and the operational reliability of the pump are not substantially degraded". The typical POR range for pumps running continuously at speeds less than or equal to 4500 rpm is 70 to 120% of BEP. The AOR is a range of flow rates, inclusive of POR, over which the service life of a pump, although reduced, is within design limits. Unlike the POR which has set parameters established by the Hydraulic Institute, the AOR determined by the manufacturer, stating the pump can operate continuously within in an allowable range.

Image 4: Preferred & Allowable Operating Regions



Operating outside of the AOR can significantly reduce the pump's performance, increase maintenance costs and operations, shorten its lifespan, and possibly void the manufacturer's warranty. Great care is taken by engineers and manufacturers to simulate flow and internal environments in the design and development of their pump products, and extensively testing their designs to ensure their product will perform as indicated.

Strategies to maintain pump operations near BEP include:

- **Proper pump selection and sizing:** Choose pumps that are appropriately sized for the specific application and operate at or near BEP.
- **Regular maintenance and monitoring:** Conduct routine maintenance and performance (flow, pressure, and power) monitoring to identify and address any issues early.

- **Variable frequency drives (VFD):** Use VFDs to adjust pump speed and maintain proper operation near BEP under varying system demands.
- **System optimization:** Optimize system components, such as pipe diameter and valve placement, to minimize resistance and ensure smooth operation.

Conclusion

Operating too far to the left or right of BEP can lead to significant inefficiencies, increased operational costs, and potential damage to pump components. By understanding these dangers and implementing strategies to maintain operation near BEP, you can ensure optimal performance, extend the lifespan of your equipment, and achieve substantial cost savings.

Wilo is Your Solutions Provider

Wilo USA offers a suite of powerful tools designed to assist individuals in optimizing pump systems. Wilo's range of engineering tools includes sophisticated software and resources to streamline projects. Utilize Wilo's pump selection software-Intelliquip® to easily find the perfect pump for specific applications, ensuring optimal performance and efficiency.

Wilo has developed and deployed best in-class engineering design and simulation processes to develop their products. This enables Wilo to design and launch products virtually, and both study and predicted detail flow features and performance parameters in their products and systems. As such, they can predict the thrust loads that are exerted on the shaft and other components across the performance envelope, including off-design conditions.

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