

The Energy Behind the Flow

Velocity, Pressure, and Head Explained

In pump systems, **velocity, pressure, and head** are different expressions of mechanical energy acting on a **fluid**. Understanding how they interact helps engineers and operators properly size pumps, interpret **pump curves**, minimize losses, and troubleshoot performance issues.

The Three Forms of Energy in a Pump System

Velocity (**Kinetic Energy**)

Velocity is how fast the fluid is moving, typically expressed in feet per second (ft/s) or meters per second (m/s). In pump engineering, this energy is expressed as velocity head, which represents a portion of **total head** (TH) due to fluid motion.

- No motion (velocity) = no kinetic energy | Higher velocity = more kinetic energy
- Increases with smaller pipe diameters or higher flow rates
- Excessive velocity leads to
 - Higher friction losses
 - Noise and vibration
 - Erosion and wear

Velocity represents this kinetic energy:

$$\text{Velocity Head} = \frac{V^2}{2g}$$

V=Fluid Velocity (ft/s or m/s) and g = acceleration due to gravity (32.2 ft/s² or 9.81 m/s²)

Pressure (**Force Energy**)

Pressure describes how hard the fluid pushes on its surroundings and is commonly measured in psi or bar.

- Pumps increase pressure by adding energy to the fluid
- Pressure varies with elevation and fluid density
- Pressure alone does not fully describe pump performance
- Pressure measures the force a liquid exerts per unit area, expressed in psi, kPa, or bar. Unlike head, pressure depends on fluid density.

Pressure is simply one expression of head:

$$\text{Pressure (psi)} = \text{Head (ft)} \times \text{Specific Gravity} \times 0.433$$

Head (Energy per Unit of Weight)

Head is the most important concept in pump engineering. It represents energy per unit weight of fluid that a pump imparts to a liquid and is commonly expressed as the vertical height the liquid could be lifted. It is measured in feet (ft) or meters (m). Head is independent of fluid density, which is why pump curves are always expressed in head, and not pressure.

Head consists of three components:

- **Elevation head:** energy from height
- **Pressure head:** energy from pressure
- **Velocity head:** energy from fluid motion

Velocity measures how fast the liquid is moving through the system.

Pressure measures how hard that liquid pushes on its surroundings.

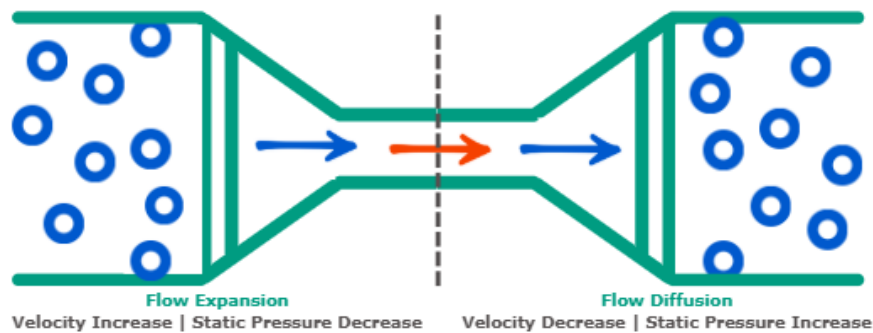
Head measures how high a pump can lift a liquid.

How Velocity, Pressure, and Head are Connected

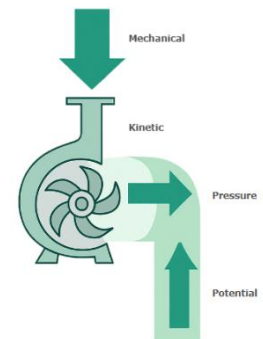
These three energy forms are tied together by Bernoulli's Principle, which states "For steady, incompressible flow with negligible losses, the total mechanical energy of a flowing fluid equals the sum of elevation head, pressure head, and velocity head".

Total Head = Elevation Head + Pressure Head + Velocity Head

In a constant-energy system, increasing fluid velocity often results in a corresponding decrease in static pressure, and vice versa.



Pumps add energy in the form of head, which may be expressed as increased pressure, increased velocity, or a combination of both depending on system conditions. Changes in pipe size redistribute energy between velocity and pressure, but the total head delivered remains governed by the pump and its operating point.



Why Pumps are Rated in Head, Not Pressure

Head is the universal language of pump performance, allowing comparisons to select and analyze pumps across a wide range of applications and fluids.

- For a given pump operating point, head is independent of fluid density
- Pressure changes with specific gravity, but head does not
- Using head allows one pump curve to apply to:
 - Water
 - Glycol mixtures
 - Oils and other liquids

Velocity varies with flow rate and pipe size.

Pressure varies with density.

Head is constant.

Practical Impacts on Pump Systems

The relationship between velocity, pressure, and head has direct, real-world consequences for how pump systems are designed, operated, and maintained. Pipe sizing, friction losses, and system behavior are all influenced by how energy is distributed within the system, and understanding these interactions helps improve efficiency, reduce wear, and quickly diagnose performance issues.

Pipe Size

- Small pipes → higher velocity → higher friction losses
- Larger pipes → lower velocity → improved efficiency

System Losses

- Friction losses increase approximately with the square of velocity
- Most system heads are consumed by overcoming friction, not elevation

Troubleshooting

- High pressure readings may indicate restrictions
- Low pressure with normal head may point to excessive velocity or air entrapment

Summary

Velocity, pressure, and head describe how energy moves through a pump system, each playing a distinct but interconnected role. As summarized below, velocity reflects fluid speed and influences friction losses and wear, pressure represents the force exerted on pipe walls and varies with fluid density, and head represents the energy added by the pump and serves as the basis for pump selection and performance evaluation.

Term	What it Represents	Why it Matters
Velocity	Fluid speed	Affects losses and wear
Pressure	Force on pipe walls	Varies with density
Head	Energy added by the pump	Basis for pump selection

Pumps do not create pressure directly; instead, they add head, which the system converts into pressure, velocity, or elevation depending on operating conditions. Understanding how these elements work together provides clearer insight into pump behavior, system efficiency, and long-term reliability.

Wilo is Your Solutions Provider

At [Wilo](#), we go beyond supplying pumps. We deliver complete solutions by understanding the energy behind the flow. By applying a deep knowledge of how head, pressure, and velocity interact within real-world systems, Wilo helps customers select, design, and optimize pumping solutions that perform efficiently and reliably over their entire lifecycle. From application engineering and system analysis to high-efficiency products and lifecycle support, Wilo partners with you to ensure energy is used wisely, performance is predictable, and systems operate at their best.

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