Radial-Flow Pumps: Volute Pump
Radial-Flow Pumps: Diffuser Pump
Axial Flow Pump

Pump Performance Parameters

- Capacity,
- Head,
- Power,
- Efficiency,
- Required Net Positive Suction Head, and
- Specific Speed
Capacity

The capacity of a pump is the amount of water pumped per unit time. Capacity is also frequently called discharge or flow rate (Q). In English units it is usually expressed in gallons per minute (gpm). In metric units it is expressed as liters per minute (l/min) or cubic meters per second (m³/sec).

Head

It is the amount of energy added to the water between the suction and discharge sides of the pump. Pump head is measured as pressure difference between the discharge and suction sides of the pump.

Pressure or Head

Pressure and head are two different ways of expressing the same value. Usually, when the term "pressure" is used it refers to units in psi (pounds per square inch) in the English system or kilopascals (kPa) in metric units, whereas "head" refers to ft in English units or meters (m) in metric units. A column of water that is 2.31 ft high will exert a pressure of 1 psi.
Power Requirements – Water Power

The power imparted to the water by the pump is called water power.

\[ P_h = Qh \]  \hspace{1cm} (14.1)

\[ P_w = \frac{Qh}{3960} \]  \hspace{1cm} (14.2)

Power Requirements – Brake Power

\[ P_b = \frac{P_w}{\eta_p} \]  \hspace{1cm} (14.3)

Power required to be delivered to the pump shaft, necessary to impart desired flow and head to the water.

Efficiency

Pump efficiency is the percent of power input to the pump shaft (the brake power) that is transferred to the water.

\[ \eta_p = \frac{P_w}{P_b} \]  \hspace{1cm} (14.4)

The efficiency of a pump is determined by conducting tests.
Specific Speed

Specific Speed is constant for any geometrically similar pump. It is an index number which classifies pump impellers.

\[ n_s = N Q^{1/2} h^{-3/4} \quad (14.5) \]

For a given head and capacity, suction lift is greater for a pump with lower specific speed.
The required net positive suction head ($NPSH_r$) is the amount of energy required to prevent the formation of vapor-filled cavities of fluid within the eye of the impeller. The formation and subsequent collapse of these vapor-filled cavities is called cavitation and is destructive to the impeller.

The $NPSH$, to prevent cavitation is a function of pump design and is usually determined experimentally for each pump.

The head within the eye of the impeller, also called net positive suction head available ($NPSH_a$), should exceed the $NPSH$, to avoid cavitation.
Available Net Positive Suction Head

\[ NPSH_a = h_{atm} - h_{s} - h_f - h_{vap} - F_S \]  \hspace{1cm} (14.6)

where:
- \( NPSH_a \) = avail. net positive suction head
- \( h_{atm} \) = barometric pressure
- \( h_s \) = suction lift or head
- \( h_f \) = suction side friction loss
- \( h_{vap} \) = water vapor pressure
- \( F_S \) = factor of safety

1. \( Q_2 = \left( \frac{N_2}{N_1} \right) Q_1 \)  \hspace{1cm} (14.7)
2. \( h_2 = \left( \frac{N_2}{N_1} \right)^2 h_1 \)  \hspace{1cm} (14.8)
3. \( P_{B2} = \left( \frac{N_2}{N_1} \right)^3 P_{B1} \)  \hspace{1cm} (14.9)

where:
- \( Q_1, h_1, P_{B1} \) are determined at speed \( N_1 \) (rpm)
- \( Q_2, h_2, P_{B2} \) are determined at speed \( N_2 \) (rpm)

Affinity Laws

1. \( Q_2 = \left( \frac{D_2}{D_1} \right) Q_1 \)  \hspace{1cm} (14.10)
2. \( h_2 = \left( \frac{D_2}{D_1} \right)^2 h_1 \)  \hspace{1cm} (14.11)
3. \( P_{B2} = \left( \frac{D_2}{D_1} \right)^3 P_{B1} \)  \hspace{1cm} (14.12)

where:
- \( D_1 \) = initial diameter of the impeller
- \( D_2 \) = diameter of the impeller after trimming
**Cavitation**

The process of cavitation is caused by the reduction in pressure behind the impellers to the point that the water vaporizes (boils).

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**Priming of Centrifugal Pumps**

All centrifugal pumps must be primed by filling them with water before they can operate. This causes water to flow into the pump when pressure at the eye of the impeller is reduced below atmospheric pressure as the impeller rotates.
### Problem Possible Causes

<table>
<thead>
<tr>
<th>Problem</th>
<th>Possible Causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Liquid Delivered</td>
<td>• Pump not primed  • Insufficient available NPSH  • Suction line strainer clogged  • End of suction line not in water  • System total head higher than pump total head at zero capacity.</td>
</tr>
<tr>
<td>Pump Delivers Less Than Rated Capacity</td>
<td>• Air leak in suction line or pump seal  • Insufficient available NPSH  • Suction line strainer partially clogged or of insufficient area  • System total head higher than calculated  • Partially clogged impeller  • Impeller rotates in wrong direction  • Suction or discharge valves partially closed  • Impeller speed to low  • Impeller installed in reverse direction.</td>
</tr>
<tr>
<td>Loss of Prime While Pump is Operating</td>
<td>• Water level falls below the suction line intake  • Air leak develops in pump or seal  • Air leak develops in suction line  • Water vaporizes in suction line.</td>
</tr>
<tr>
<td>Pump Is Noisy</td>
<td>• Cavitation  • Misalignment  • Foreign material inside pump  • Bent shaft  • Impeller touching casing.</td>
</tr>
<tr>
<td>Pump Takes Too Much Power</td>
<td>• Impeller speed too high  • Shaft packing too light  • Misalignment  • Impeller touching casing  • System total head too low causing the pump to deliver too much liquid  • Impeller rotates  • Impeller installed in wrong direction.</td>
</tr>
</tbody>
</table>
**Total Dynamic Head**

\[ h_t = h_s + h_d + h_p + h_f + h_v \]  

(14.13)

Where:

- \( h_t \) = total dynamic head of the system
- \( h_s \) = static head (static lift + static discharge)
- \( h_d \) = drawdown
- \( h_p \) = operating head (required pressure)
- \( h_f \) = friction loss head
- \( h_v \) = velocity head

**System Curves**

![System Curves Diagram]

**Pump Curves**

![Pump Curves Diagram]
The total system head can vary with time due to variations in well drawdown, friction, operating conditions, and static water level changes throughout the seasons.
System Curves – Water Table Drop

Pumps Operating in Series

Pumps Operating in Series
Pump Operating Point