TOPICS

• DEFINITION
• COMPONENTS
• PUMP CURVES
• THE PIPE SYSTEM
• NPSH
• VFD OPERATION
DEFINITION

A CENTRIFUGAL PUMP IS A ROTODYNAMIC MACHINE THAT CONVERTS ROTARY MOTION INTO PRESSURE

ROTO = SPIN
DYNAMIC = CHANGE
**Why Use a Pump?**

Water does not flow uphill

Pumps are used to lift water from a lower elevation to a higher elevation

Pumps are also used to generate flow and/or pressure
- in a jet aeration header
- to pump downhill
Why Use a Centrifugal Pump?

Available in a wide range of sizes – discharges from 1” to 12ft and bigger

Handle a wide range of head and flow conditions

Limitations:
• cannot handle entrained air – 3% max
• cannot handle viscous liquids
PUMP TYPES

Centrifugal pumps come in a wide variety of styles:

- end suction
- in-line
- vertical multistage
- submersible
- axial-flow
- split case
- double suction
- horizontal multistage
- self-priming
- regenerative
**Split case**

Suction and discharge on opposite sides

Double-hung impeller

Shaft is perpendicular to flow

Casing is split into top and bottom halves

Top half is lifted off for service
End suction

Suction is inline with the shaft

Overhung impeller mounted on end of shaft

Can be close-coupled, or

Frame-mounted – pump and motor are separate units on common base plate
End suction

- **HEAVY DUTY THRUST BEARING WITH DOUBLE LOCKNUTS**
- **ALLOY-STEEL SHAFT GROUND TO SIZE**
- **SHIM ADJUSTMENT TO COMPENSATE FOR WEAR**
- **HEAVY CAST-IRON FRAME, VERY RIGID**
- **FULL-SIZE PASSAGEWAYS IN IMPELLER & CASING**
A submersible pump is a close-coupled end suction pump with an integral electric motor.
Vertical turbine

Long-shaft pump

The bowl is down in the water

The discharge head is mounted above

Line shaft runs up the discharge column

Add multiple bowls in series for high head
COMPONENTS

WET END

DRIVER
The driver provides the power to do the work.

Can be coupled to, or integral with, the pump shaft.

Must be carefully aligned and supported.
The amount of power needed to move the liquid depends **only** on the wet end.

In theory, you can mate any size wet end with any size driver.

**BUT USING AN UNDERSIZED DRIVER WILL OVERLOAD THE MOTOR!**
Horsepower

Power is a measure of work per time

\[ \text{Work} = \text{Force} \times \text{Distance} \]

\[ \text{Power} = \frac{\text{Work}}{\text{Time}} \]

One horsepower is the amount required to raise 33,000 lbs up 1 foot in 1 minute
Pump input or brake horsepower (bhp) is the actual horsepower delivered to the pump shaft. Pump output or hydraulic horsepower (whp) is the liquid horsepower delivered by the pump. These two terms are defined by the following formulas.

\[
\text{whp} = \frac{Q \times \text{TDH} \times \text{Sp. Gr.}}{3960}
\]

\[
\text{bhp} = \frac{Q \times \text{TDH} \times \text{Sp. Gr.}}{3960 \times \text{Pump Efficiency}}
\]

\[
\text{Pump Eff} = \frac{\text{whp}}{\text{bhp}} = \frac{Q \times \text{TDH} \times \text{Sp. Gr.}}{3960 \times \text{bhp}}
\]
EFFICIENCY

Overall

Motor

Pump
Also called the “liquid end”

The part of the pump that contains the pumped liquid
IMPELLER

Draws liquid into the wet end

Imparts velocity to the liquid

Throws liquid against the inside of the volute
VOLUTE

Captures the liquid exiting the impeller

Converts kinetic energy (velocity) into potential energy (pressure)

Directs liquid into the discharge pipe
Also called the **casing** or **pump housing**

Volute = spiral

Converts the motion of spinning liquid into pressure

Forces liquid into the piping at high pressure
WEAR RINGS

Form a running seal between the suction (low pressure) and discharge (high pressure)

Increase efficiency by preventing recirculation

Can be easily replaced to maintain close running clearance
Seals

Packing
Lip seal
Mechanical seal
Dynamic seal

Purpose: seals off the opening where shaft enters volute
Seals

Lubricated with water

Use external flush water for pumping grit and rags

Seals are designed to leak, at a slow rate
IMPELLER TYPES

OPEN & CLOSED CHANNEL

NON-CLOG

GRINDER

VORTEX

CHOPPER

PROPELLER
IMPELLER TYPES

Closed vs. Open
IMPELLER TYPES

NON-CLOG

• High efficiency
• Smooth passageways
• No abrupt turns
• Clog resistant
IMPELLER TYPES

GRINDER

• Like a garbage disposal
• Cutting ring, wheel, etc.
• Low efficiency
• Used with small piping
IMPELLER TYPES

VO RT E X

• Also called recessed, swirl, or torque flow

• Creates a “tornado” effect to suck up liquid

• Liquid does not pass through impeller – good for abrasive liquids
IMPELLER TYPES

CHOPPER

• Screw shape
• Cutting plate
• Low efficiency
IMPELLER TYPES

PROPELLE

• Pure axial flow
• High flow, low head
• Sensitive to inlet flow
A centrifugal pump can deliver a wide range of flows. As flow increases, the head decreases. Pump efficiency varies across the flow range. We plot head vs. flow to get the *pump curve*, or *performance curve*.
PUMP CURVES
WE TALK ABOUT FLOW AND HEAD

FLOW = **GPM**

The rate of liquid (volume per time) passing through the pump. Mgd, cfs, m³/hr, etc.

HEAD = **FEET**

The amount of energy added to the liquid by the pump.
PUMP CURVES

WE TALK ABOUT **Head** in **feet of liquid**

If a pump runs at 20 feet of head, it will support a column of liquid 20 feet high.
PUMP HEAD

The term “head” likely derives from the elevation difference available to power a waterwheel.
Parallel and Series Pumping

Parallel: Pumps operate side-by-side
Provides more flow

Series: Pumps operate in-line
Provides more head
PUMP CURVES

WHERE WILL THE PUMP OPERATE?

WHERE IT REACHES A **BALANCE** WITH THE PIPING **SYSTEM**
THE PIPE SYSTEM

THE PIPE SYSTEM CREATES RESISTANCE TO FLOW

THE AMOUNT OF RESISTANCE IS BASED ON STATIC AND DYNAMIC COMPONENTS
THE PIPE SYSTEM

HOW HIGH?
The elevation difference is the static head – it is independent of the flow rate

HOW FAR?
Longer pipe runs create more resistance

THROUGH WHAT?
There is friction as the liquid runs through the pipe. Friction depends on the pipe size and roughness.
Pipe Diameter & Roughness
EFFECT OF PIPE LENGTH
EFFECT OF FLOW RATE OR ROUGHNESS
EFFECT OF PIPE DIAMETER
THE SYSTEM CURVE
WE CAN SHOW THE RESISTANCE OF THE PIPE SYSTEM AS A SYSTEM CURVE
THE PUMP RUNS WHERE IT MEETS THE SYSTEM CURVE
System Head Curves

A system head curve is valid for only one condition in the pipe system.

Changing the system (partially closed valve) will change the shape of the system head curve.

Changing water surface elevation will change the static head and shift the system curve up or down.
THE SYSTEM MATTERS!
VERIFYING THE OPERATING POINT
Using Pressure Gauges

To find the total dynamic head of the system, the following must be added to the gauge reading:

1. Difference in elevation from the surface of the liquid being pumped to the center line of the gauge. (In most cases, this is an ever changing value due to draw-down.)

2. The friction losses from the pump outlet to the center line of the gauge. (This also is an everchanging value due to draw-down, and can be computed by the use of system head curves.)

3. The velocity head at point of gauge installation.
BEST EFFICIENCY POINT
BEST EFFICIENCY POINT

• The “sweet spot”

• Operation at BEP results in lowest operating cost and longest service life

• BUT PUMP SELECTION ALWAYS INVOLVES TRADE OFFS
  • SOLIDS HANDLING SIZE
  • SPEED
  • COST
OFF-PEAK OPERATION

- Reduced efficiency
- High bending forces - wear on seals, bearings
- Vibration
- Clogging
- Temperature rise
- Cavitation
- Motor overload

![Relative Radial Load vs Pump Flow](image)
POWER CURVE
NPSH CURVE

NPSH = NOT PUMPING SO HOT?

NPSH = NET POSITIVE SUCTION HEAD

IT’S THE POSITIVE PRESSURE REQUIRED AT THE PUMP INLET

NEED TO COMPARE AVAILABLE TO REQUIRED NPSH
NPSH AVAILABLE

4b SUCTION SUPPLY OPEN TO ATMOSPHERE
—with Suction Head

\[ NPSH_A = P_B + L_H - (V_P + h_f) \]
WHAT **HURTS** THE NPSH?

- **INSUFFICIENT SUBMERGENCE**
- **AIR ENTRAINMENT**
- **SUCTION PIPING (DRY-PIT PUMPS)**
- **HOT LIQUID**
NPSH CURVE
Cavitation

Cavitation is the formation of vapor bubbles in any flow that is subjected to an ambient pressure equal to or less than the vapor pressure of the liquid being pumped.

Cavitation damage is the loss of material produced by the collapse of the vapor bubbles against the surfaces of the impeller or casing.

Cavitation may be present in combination with erosion and corrosion - especially in wastewater
Cavitation - Causes

1 - Insufficient NPSH available
   Occurs on the low-pressure, or visible, surface of the impeller vane

2 - Recirculation - partial reversal of flow through the impeller
   Occurs on the high-pressure, or invisible, surface of the impeller vane
FIG. 1 Examining the pressure side of the inlet vanes for suction recirculation damage.
Cavitation - Diagnosis
Cavitation, Corrosion, and/or Erosion?
CHANGING THE FLOW AND HEAD

• BIGGER OR SMALLER IMPELLER
• CHANGE SPEED WITH A VFD
BIGGER OR SMALLER IMPELLER

Caution!
A bigger impeller might overload the motor
CHANGE SPEED WITH A VFD

VFD = Variable Frequency Drive
Change speed with a VFD

Allowable Operating Region (AOR): 50% to 125% of BEP flow (per mfr.)

Preferred Operating Region (POR): 70% to 120% of BEP flow (per HI)
CHANGE SPEED WITH A VFD

CAUTION!

When you turn down the VFD, the pump may run at a different spot on its curve.

You might be doing more than simply changing the flow rate!
CHANGE SPEED WITH A VFD

CAUTION!

RUNNING THE PUMP TOO SLOW FOR TOO LONG CAN CAUSE PROBLEMS

• CLOGGING

• VIBRATION

• HIGH BENDING FORCES
? QUESTIONS ?
THE END!