PRACTICAL PHYSICS FOR ENERGY-EFFICIENT FLUID SYSTEMS
FIRST LAW OF THERMODYNAMICS

Energy can neither be created nor destroyed, only altered in form.

\[ \Delta U = Q - W \]
NEWTON’S 3 LAWS OF MOTION

1. An object in motion will continue in a straight line at constant velocity unless a force acts on it.

2. The force acting on an object is equal to its mass times acceleration.

3. When two objects interact, they apply forces to each other of equal magnitude and opposite direction.
**PASCAL’S LAW**

\[ F = PA \]

*Blaise Pascal*

**BERNOULLI’S LAW**

\[ TP = SP + \frac{1}{2} \rho v^2 + \rho gh \]

*Jacob Bernoulli*

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PIPE AND DUCT FITTING LOSSES

1

2

3
Helical Flow

Water moving through a river bend develops a corkscrew motion that is downward along the outer bank, further increasing erosion, and upward along the inner bank, resulting in deposition.
PIPE AND DUCT FITTING LOSSES

View from downstream
PIPE AND DUCT FITTING LOSSES
PUMP PERFORMANCE CURVE AND SYSTEM INTERACTION

PUMPING SYSTEM HYDRAULIC OPERATING POINT

FLOW, gpm

HEAD, feet

1 Pump
System
2 Pump

H.M. WHITE
PHYSICS OF FLUID SYSTEMS
PUMP FLOW CONTROL METHODS – THROTTLING vs VFD

PUMPING SYSTEM THROTTLED OPERATING POINT

PUMPING SYSTEM VFD OPERATING POINT
20% SPEED REDUCTION

Flow:  \( \frac{Q_2}{Q_1} = \frac{1424}{1780} = 80\% \)

Head:  \( \frac{H_2}{H_1} = \left(\frac{1424}{1780}\right)^2 = 64\% \)

Power:  \( \frac{P_2}{P_1} = \left(\frac{1424}{1780}\right)^3 = 50\% \)

For a given impeller and density:

**Flow:**

\[
\frac{Q_2}{Q_1} = \frac{\omega_2}{\omega_1}
\]

**Head:**

\[
\frac{H_2}{H_1} = \left(\frac{\omega_2}{\omega_1}\right)^2
\]

**Power:**

\[
\frac{P_2}{P_1} = \left(\frac{\omega_2}{\omega_1}\right)^3
\]
Q: What is the single most expensive item associated with this brand new pump?

A: THE ELECTRICITY TO RUN IT FOR THE NEXT 10, 20, 30 YEARS!
IN SITU PUMPING SYSTEM HYDRAULIC OPERATING POINT

- \( \text{HEAD, feet} \)
- \( \text{FLOW, gpm} \)

Graph showing the hydraulic operating point for an in situ pumping system with data points for 1 pump and system performance, along with field test results.
10-YEAR ELECTRICITY COST TO FIX

- Open Throttle: $10/hp
- Change Impeller: $25/hp
- VFD: $50/hp
- Run 2\textsuperscript{nd} Pump: $125/hp
FAN SYSTEM EFFECTS

1.2 x V/1000

"Breaking the Fan’s Back"

Right Angle Turns At Fan Inlet

- Inlet with 3-piece elbow
- Inlet with rectangular inlet duct (POOR)
- Inlet with special designed inlet box

Counter-rotating swirl

Impeller rotation
MULTIPLE FAN SYSTEM EFFECTS
SUMMARY OF FLUID PHYSICS CONCEPTS

• Mass particles within fluid systems move independently in response to localized forces.
• Every acceleration, deceleration or direction change requires force.
• Force derives from pressure.
• Total pressure is the sum of static, elevation, and velocity pressures, which can be converted from one to another.
• Generating pressure requires energy conversion.
• Fluid system pressure losses vary according to velocity pressure, with the square of flow.
• Every energy conversion generates entropy, permanently reducing total future energy conversion opportunities and available work.
• All energy eventually ends up as heat.
MORE INFORMATION


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QUESTIONS
and
DISCUSSION