Hydraulic Fundamentals

- Physics is the core of engineering
- This field of physics is fluid dynamics
- Piping affects the heart of the system (the pump)
- Water and wastewater applications
### Important Properties

- S.G. 1.0 @ 60°F to 70°F
- “Practically” Incompressible
- One gallon of water = 8.333 lbs @ 65 °F
- One Cu.Ft. = 62.32 lbs @ 68 °F = 7.48 gallons
- One psi equals 2.31 ft. of water @ normal temperatures
- A column of water 2.31 ft. high = 1 psi
- Atmospheric pressure @ sea level is defined as 14.696 pounds per square inch absolute (psia)
- Preston, Idaho – (4740 ft) 12.35 psia

### Question

- The gauge at the base of a 5000 gallon tank of water, 100 ft. high, reads 43.31 psi.

- How many psi does 5 gallons of water @ 100 feet high read?

*Water weighs 8.333 lbs/gal

### Physical Characteristics

- Temperature
- Taste
- Color
- Odor
- Turbidity
Water Contains Dissolved Gases

- Changes in
  - Temperature
  - Pressure
- Causes vapor pockets, gasses come out of suspension, causing cavitation

Pumps Don’t Suck

- Contrary to popular belief, pumps don’t suck
- Pumps use kinetic energy to impart energy to the liquid at a greater velocity than it possessed when it entered.
- The velocity is then converted to pressure or “head”
Altitude vs Pressure

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Liquid Flow

- Laminar – particles of the liquid follow separate non-intersecting paths with little or no eddying or turbulence
- Reynolds Number – R Value
  - Less than 2000 = Laminar
  - 2000-4000 = Critical Zone (considered turbulent for friction or pressure, drop calculations)
- Over 4000 = Turbulent Flow

\[ V = \text{Average Velocity} \quad \text{ft/sec} \]
\[ D = \text{Average diameter} \quad \text{ft} \]
\[ v = \text{Kinematic velocity of the fluid} \quad \text{ft/sec} \]
\[ @ 60^\circ F, v = 1.216 \times 10^{-5} \text{ ft}^2/\text{sec} \]
\[ R = \frac{VD}{v} \]

Laminar Flow R value = Less than 2000
Different Pipe Materials Offer Different Friction or Head Loss

Pressure is Exerted equally in all Directions “BRAKES”

Piping Comes From All Directions and Levels

Every twist, turn, fitting and valve affects flow configurations
How do you determine whether you have clockwise or counterclockwise rotation on a pump?
What do – Suction Diffusers, Straightening Vanes and Flow Inducers - have in common?

OR

* 5-10 pipe diameters upstream
* Pump impellers don’t do air

Correct or Incorrect?

A. Concentric reducer

Correct or Incorrect?

B. Eccentric reducer with straight side on bottom
Correct or Incorrect?

C. Eccentric reducer with straight side on top

NEVER CONTROL PUMP FLOW FROM THE SUCTION SIDE!

THE DISCHARGE PIPE AND THE MANY APPURTENANCES

Pipe Line Flow

*Look at it like a train
THE SYSTEM
STATIC/DYNAMIC

STATIC HEAD

The Bernoulli Equation

The Bernoulli equation describes the total energy of fluid in a pipe. The total energy at any point in the pipe is the sum of the pressure head, potential head, and kinetic head. This total energy of fluid flow can be calculated using the following equation:

Equation 7.1

The Bernoulli equation accounts for the total energy of the fluid in the system. Assuming there are no losses due to friction between the fluid and the pipe wall, the total energy must be constant throughout the system.

Within the fluid mixture, there can be losses between the flow and the pipe wall. These losses are caused by friction and heat, and can be represented in the equation. In effect, the Bernoulli equation for a fluid flow in a pipe is Equation 7.1. Therefore, loss for the energy flow. This is reflected in the total energy in the system.

The Bernoulli equation allows you to determine the pressure and velocity head in the system using the following equation:

Equation 7.1

To use the Bernoulli equation, you need to measure the pressure and velocity head in the system.

DYNAMIC HEAD

THE “HEART” OF THE SYSTEM?
The System Requirements are what Determines the Pump Selection

- Raw water pumping
- Water – transfer
- Water – boosting
- Wastewater transfer – non clog
- Wastewater collection
- Ejectors
- Grinders
- Effluent

CENTRIFUGAL FORCE PUMP
DEVELOPED IN EUROPE, LATE 1600’S

1. BORE HOLE
2. Stream of water tangent to the circle
3. Increase speed (ft/sec)
4. Greater force = greater volume/greater distance
What is the Key Element in Maintaining Pump Pressure and Efficiency?

Impeller Types
Enclosed Multi-Vane
- Small or no solids handling
- Opening between front and back shrouds determine GPM
- Diameter and RPM determine head
- Most efficient design
  - Single-Double Suction
  - Multi-Stage-Vertical
  - Horizontal – Water - Effluent

Recessed or Vortex
- Sludge laden
- Long stringy items
- Least efficient
- Good problem solver

Enclosed Non-Clog
- 2-3 vane
- Spherical solids handling
- No such thing as NON-CLOG
Enclosed Single Vane
- High head
- Non-clogging type

Open Single Vane, Screw Type
- Sludge laden material

Grinder
- Wastewater collection systems
- Macerates wastewater solids
- Generally low flows at high heads thru small diameter pipes

Pump Selection
Family of Pump Curves

Know Your Curves
- Head
- Flow rate
- Pump efficiency
- Shut off head
- Minimum flow
- Allowable operating range
  - Bracketed curve
- Best efficiency point (BEP)
- Preferred operating range
- Max flow

US GPM

Changing Head Conditions
Parallel and Series Operation

With properly selected head-capacity (H-Q) curve (preferably curves with continuously rising characteristics) and subject to certain hydraulics and mechanical restrictions in parallel and the series operation of centrifugal pumps can be employed to meet a wide range of service requirements.

In considering multiple pump operation a systems head curve for the entire capacity and head requirements must be made available. The individual pump H-Q curve must be superimposed on the system curve.

For parallel operation of two or more pumps the combined performance curve is obtained by adding horizontally the capacities of the same heads.

For series operation the combined performance curve is obtained by adding vertically the heads at the same capacity.

Since a centrifugal pump always operates at the intersection of its H-Q curve with the system curve, superimposing the system curve on the pump performance curve clearly indicates what flow can be expected and at which head each pump or its combination will operate.

Fig. 10 illustrates a two pump parallel operation. This could be expanded to a three or more pump combination or divided. In this illustration a typical H-Q curve for a single pump designed for 1000 gpm at 80 ft head is shown; two pumps in series will deliver 1000 gpm at 150 ft, or six pumps parallel will deliver 6000 gpm at 50 ft. System curves have assumed as shown. If the pumps have "suction capability" (check data) they will operate at the intersection of the H-Q curve with the system curve. Note that in this illustration the system curve is based on the assumption that there is 8 ft static head.

ELECTRICAL AND CONTROLS

Pump problems are generally electrical or piping related.
Work Performed in Pumping-HP

- One hydraulic horsepower = (hyd hp) = 33,000 ft lb/min. the useful or theoretical horsepower

- Hyd hp = lb of liquid per min x H (in feet)
  - 33,000

***The actual or brake horsepower (bhp) of a pump will be greater than the hyd hp by the amount of losses incurred within the pump through friction, leakage, etc...***

Brake HP

- Pump Efficiency = hyd hp / bhp
- Brake hp = hyd hp / pump efficiency
- bhp = gpm x H (in ft) x sp gr (1.0) / 3960 x efficiency
- Electrical hp input to motor = pump bhp / motor efficiency
- KW input to motor = pump bhp x 0.7457 / motor efficiency

For Example

- BHP = GPM x Hd / 3960 x efficiency
- BHP required for: 170 GPM x 90' / 3960 x 74% efficiency
- BHP = 1530/2930.4
- BHP = 5.22

Motor Amp Draw

- Determines the amount of load or work the motor is doing
- Higher amps = more work; Lower amps = less work
- FLA – full load amps – where the motor is rated to operate
- Service factor – H.P. over name plate
- Bearing temps
- VFD – variable freq. drive
- Soft starts on high H.P.
  - Inrush current
  - Hertz 50/60
PUMP SYSTEM CARE

...Care

- Gauges – suction & discharge
  - Mark – record or mark gauges to show required operating ranges
- Amp Draw – watch amp draw for changes

*High discharge pressure reading/ low amp?

- Measure voltage and record
- ETM – Elapse time meter – Records pump run time
- Post the pump curve – mark condition points

Questions?