BT 208

FLUID FLOW OPERATIONS IN BIOPROCESSING

Why??????

- In process industries, many raw materials and many finished products are in the form of fluids.

- These fluids must be stored, handled, pumped and processed in the factory.

- Hence technologists must be familiar with the principles that govern the flow of fluids, and with the machinery and equipment that is used to handle fluids.

- For example…….Fluids in the *food industry* vary considerably in their properties
  - Thin liquids - milk, water, fruit juices,
  - Thick liquids - syrups, honey, oil, jam
  - Gases - air, nitrogen, carbon dioxide

<u>Why??????</u> *contd.,*

- The nature of flow in pipes and reactors depends on the power input to the system & physical characters of fluid

- In fermentors, fluid properties affect process energy requirements & effectiveness of mixing which can have dramatic influence on productivity & the success of equipment scale-up.

- Fluids in bioprocessing often contain suspended solids, consist of more than one phase, and have non-Newtonian properties.

- All of these features complicate analysis of flow behavior and present many challenges in bioprocess design.

SYLLABUS

- Fluid statics
- Fluid dynamics
- Bernoulli’s equation
- Hagen Poiseuille's equation
- Friction factor
- Flow past immersed bodies
- Flow thro bed of solids
- Fluidization
- Transportation and metering of fluids
- Mixing & Agitation

FLUID……

- A fluid may be defined as a substance that does not permanently resist distortion and, hence, will change its shape.

- So…. gases, liquids, and vapors are considered to have the characteristics of fluids and to obey many of the same laws.

Compressible & Incompressible fluids

- If a fluid is inappreciably affected by changes in pressures it is said to be **incompressible**. Most liquids are incompressible.
- Gases are considered to be **compressible** fluids.

Momentum Transfer

- The study of momentum transfer, or fluid mechanics as it is often called, can be divided into two branches;
  1. fluid statics, or fluids at rest, and
  2. fluid dynamics or fluids in motion.

- Since in fluid dynamics momentum is being transferred, the term "momentum transfer" or "transport" is usually used.

Viscosity

- The viscosity (μ) of a fluid measures its resistance to flow under an applied shear stress.

- Representative units for viscosity are
  - kg/(m.sec)
  - g/(cm.sec) (also known as poise, designated by P)
  - The centipoise (cP), one hundredth of a poise, is also a convenient unit

- The *kinematic viscosity* (ν) is the ratio of the viscosity to the density:

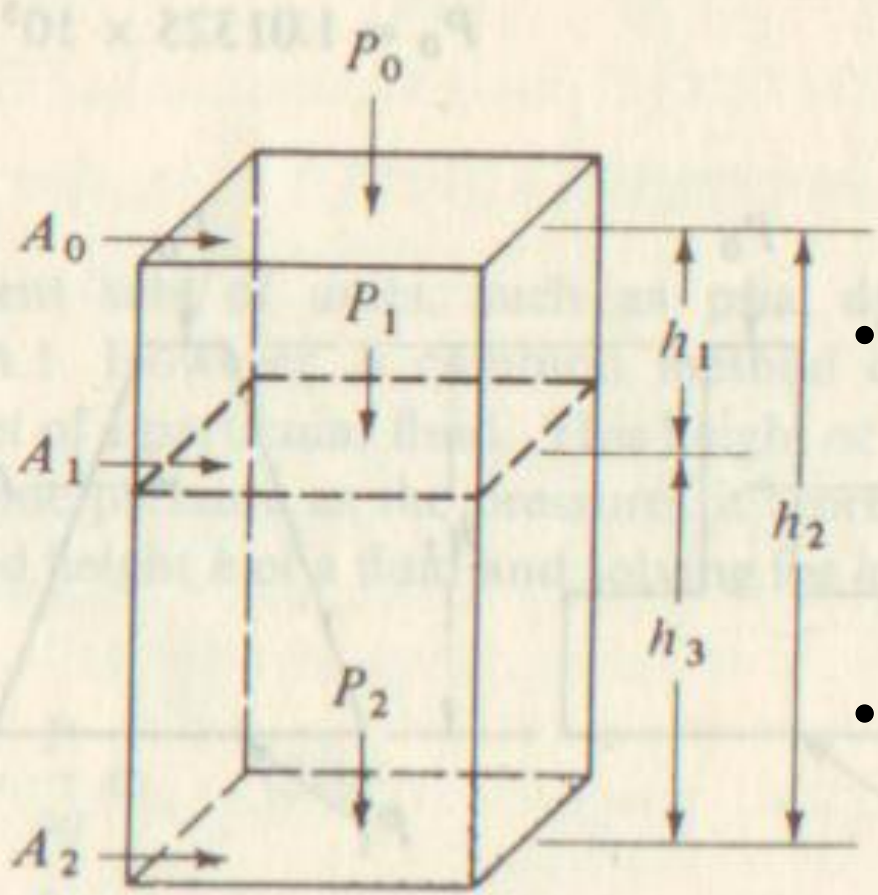
- $\nu = \mu/\rho$,

- Units of m^2/s

- **<u>Viscosity of liquids:</u>**
  - – Viscosity of liquids in general, decreases with increasing temperature.

- **<u>Viscosity of gases:</u>**
  - – Viscosity of gases increases with increase in temperature.
- @ 25^oC, $\mu_{water} = 1$ cP and
- $\mu_{air} = 1 \times 10^{-2}$ cP

Fluid Statics……



Pressure in a static fluid

- In fig., a stationary column of fluid of ht h_2 and constant CSA Area, where $A=A_o=A_1=A_2$, is shown.
- The pressure above the fluid is P_o (which could be the press of atmos above the fluid)
- Also for a fluid at rest, the force/unit area (ie Pressure) is the same at all points with the same elevation.

- We know $F = mg$ and $P = F/A$
- Total mass of fluid $= h_2 A \rho$

$$\Rightarrow F = h_2 A \rho g$$

$$\Rightarrow P = F/A = h_2 \rho g$$

- This is the press on A_2 due to the mass of fluid above it.
- To get the TOTAL PRESS P_2 on A_2, the P_o must be added

$$P_2 = h_2 \rho g + Po$$

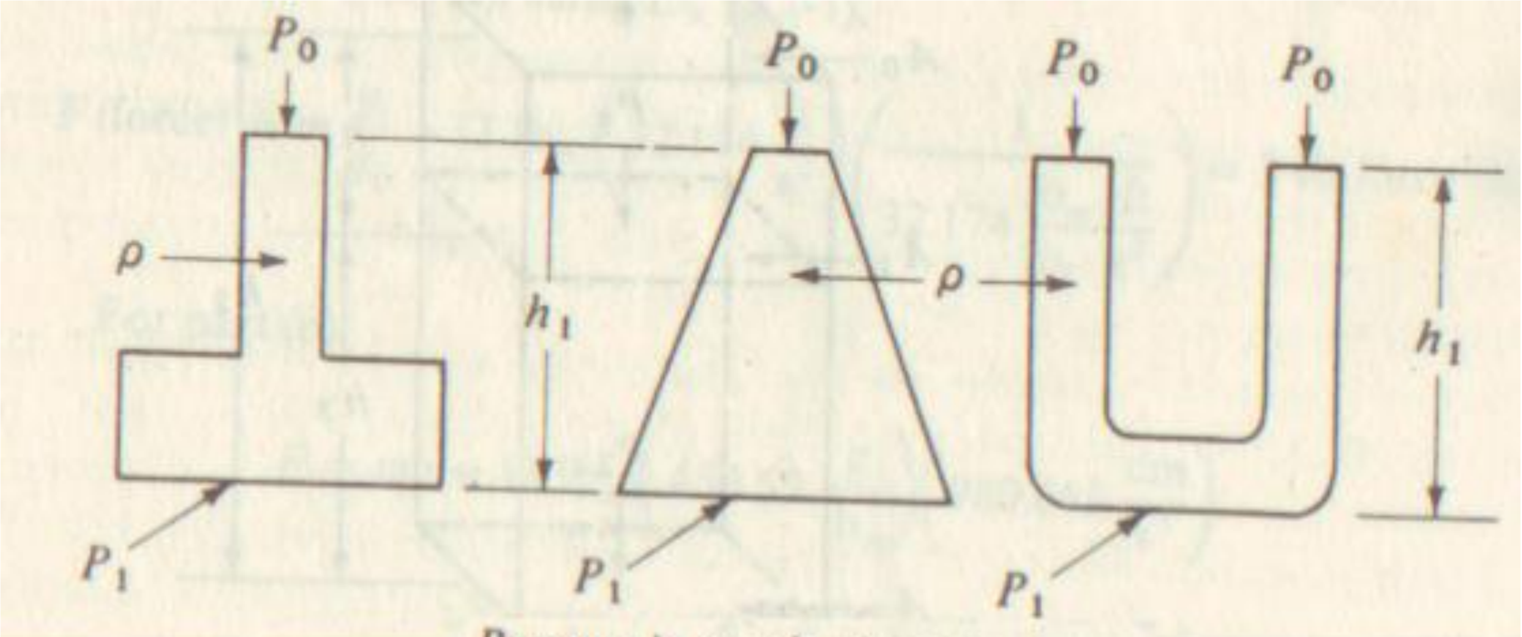
- To cal P_1,

$$P_1 = h_1 \rho g + Po$$

- The press difference bet 2 and 1 is

$$\mathbf{\Delta P = P_2 - P_1 = (h_2 - h_1)\rho g}$$

- Since it’s the vertical height of a fluid that determines the press of fluid, the shape of the vessel doesn’t affect the pressure



Pressure in vessels of various shapes.

- In the above fig the press P1 at the bottom of all three vessels is the same and equal to $h_1\rho\, g$ + Po

Head of a fluid

- Expressing the pressure in terms of head in m or ft of a particular fluid
- We know…..$P = h\rho g$
- $h = P / \rho g$