University of Mosul
College of Petroleum & Mining Engineering

Fluid Flow I

Lecture (5)

Pressure Measurement

Petroleum and Refining Engineering Department

Ass.P. Raqeeb Hummadi Rajab
Ass.L. Ghufran Faris Alrahhawi

Email: ghufranalrahhawi @uomosul.edu.iq

LECTURE CONTENTS

Pressure Measurement

Pressure Head of Liquid

Pressure Measurement

Fluid statics: is the study of fluid problems in which there is no relative motion between fluid elements.

Pressure Variation in Static Fluids:

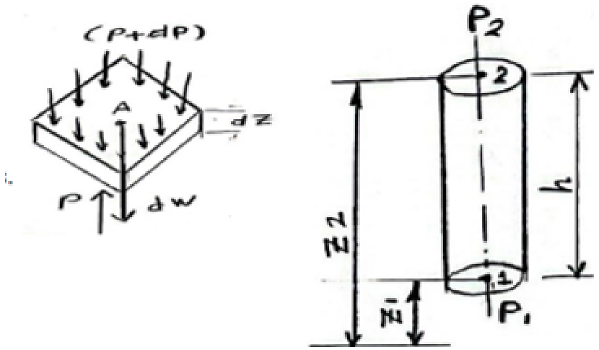


Fig. (1)

$$p = \frac{F}{A} = \frac{Force}{Area}$$

$$+\uparrow \Sigma F = 0 \rightarrow -(P + Pd)\,A - dw + PA = 0$$

$$-AdP = dw \rightarrow \qquad (*\ dw = \gamma v = \gamma Adz)$$

$$\therefore -AdP = \gamma Adz \rightarrow \therefore -dP = \gamma dz \ *\ \gamma = cons.$$

$$\int_1^2 -dp = \gamma \int_1^2 dz \qquad \text{or} \quad (p_2 - p_1) = -\gamma(z_2 - z_1)$$

$h = z_2 - z_1$ since h is positive downwards (pressure head)

$\therefore$ **or** $(p_2 - p_1) = -\gamma h$ **in final form**: $p_1 = p_2 + \gamma h$ **or:** $p_2 = p_1 - \gamma h$

If P_2 considered atmospheric pressure and taken as zero

$p_1 = \gamma h$ **(gauge pressure)**

The equation can be written as the ordinary differential equation $\frac{dP}{dz} = -\gamma$, it is one important principle of the hydrostatic, or shear-free, these equations show that the pressure does not depend on x or y (which means pressure don't varied horizontally). Since p depends only on z. **The pressure is varied with vertical depth**

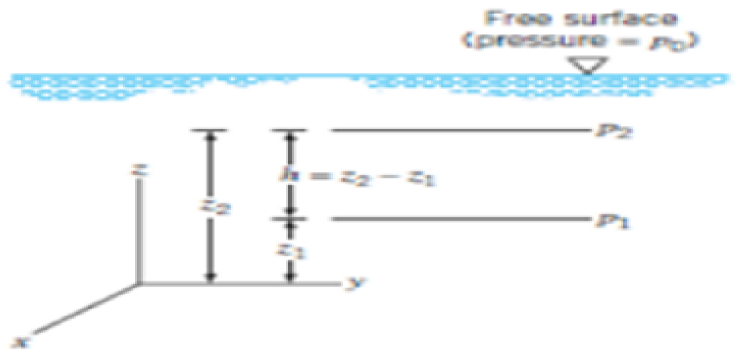
Incompressible Fluid*:* Since the specific weight is equal to the product of fluid density and acceleration of gravity ($\gamma = \rho.\text{g}$) changes in are caused either by a change in ρ or g. For most engineering applications the variation in g is negligible, so our main concern is with the possible variation in the fluid density (which it called compressible). For liquids the variation in density is usually negligible (which it called incompressible), so that the assumption of constant specific weight when dealing with liquids. For this instance, Eq. ($\frac{dP}{dz} = -\gamma$) can be directly integrated:

$\int_{p_1}^{p_2} -dp = \gamma \int_{z_1}^{z_2} dz$ **or** $(p_2 - p_1) = -\gamma(z_2 - z_1)$ **or** in final form:

$$(p_1 - p_2) = \gamma(z_1 - z_2)$$

The reference pressure would correspond to the pressure acting on the free surface (which would frequently be *atmospheric pressure*), and thus if we let $p_2 = p_o$ in above Equation it follows that the pressure p at any depth h below the free surface is given by the equation: $p_2 = \gamma h + p_o$
wherep_1 and p_2 are pressures at the vertical elevations as is illustrated in Fig. (2). Equation can be written in the compact form: $(p_1 - p_2) = \gamma h$

Equation shows that in an incompressible fluid at rest the pressure varies linearly with depth and (**h is called pressure head**) which has units of length (m) or (ft). When one works with liquids there is often a free surface, as is illustrated in Fig. (2), and it is convenient to use this surface as a reference plane.



Pressure head of a liquid:

when fluid is contained in a vessel it exerts force at all points on side, bottom and top.

h- height of liquid in cylinder; A- area of cylinder

γ- specific weight; P- pressure of liquid; F – force

Now,

total pressure force on the base of the cylinder

= weight of liquid in the cylinder

$$PA = mg = \rho \forall g = \gamma A h \rightarrow\rightarrow P = \gamma h$$

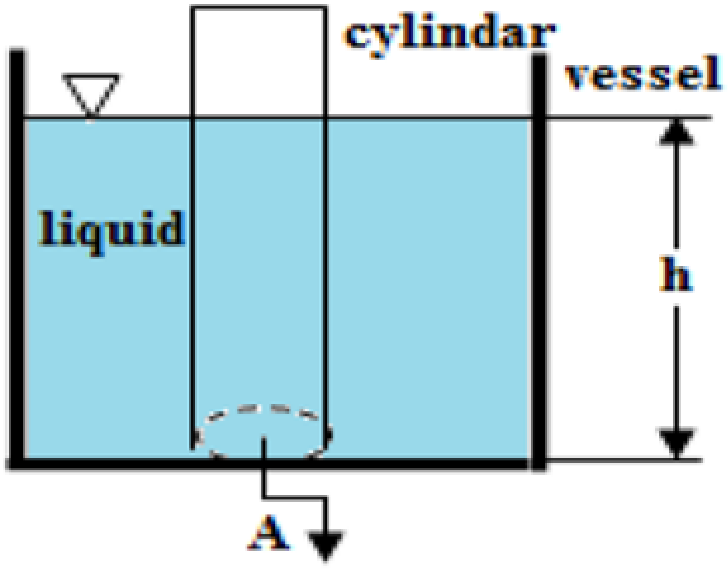


Fig. (3)

Example (1)

Find the pressure at a depth of 15m below the free surface of water in a reservoir.

$$P = \rho g h = 1000 \times 9.81 \times 15 = 147.1 kPa$$

Pascal's Law

The pressure at any point in the liquid at vessel is the same in all direction Proof: let us consider a very small wedge shaped element LMN of a liquid.

Px – horizontal pressure; Py – vertical pressure

Pz – pressure on LM; α – angle of element fluid

Fx, Fy, Fz - pressure forces on LN, NM, ML respectively.

As the element of fluid at rest, therefore:

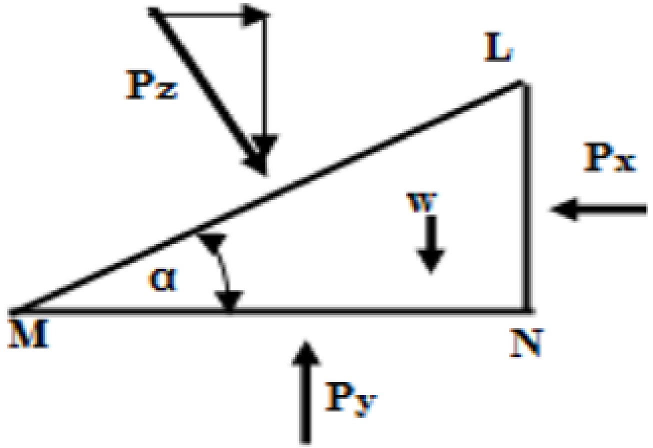


Fig. (4)

$$\Sigma Fx = 0 \rightarrow Fx = Fz\sin\alpha$$

$$PxLN = PzLM\sin\alpha, \text{ but } LM\sin\alpha = LN$$

$$PxLN = PzLN \rightarrow Px = Pz - - - -(1)$$

$$\Sigma Fz = 0 \rightarrow Fy = Fz\cos\alpha + w,$$

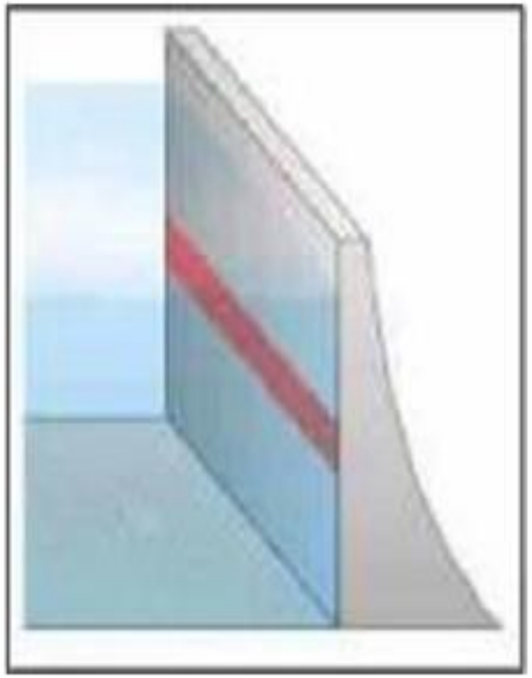
$$w = 0 \text{ very small element}$$

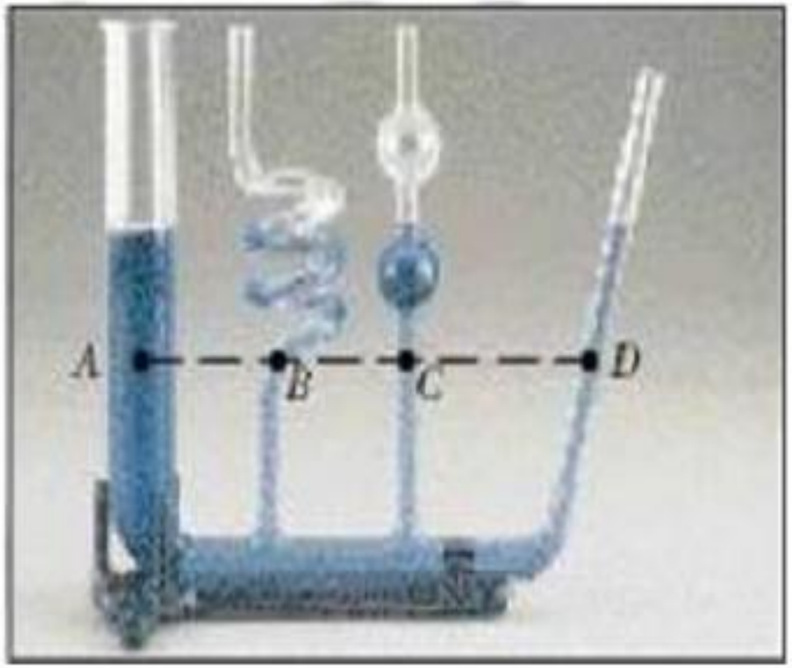
$$PyMN = PzLM\cos\alpha \text{ but } LM\cos\alpha = MN$$

$$PyMN = PzMN \rightarrow Py = Pz - - - (2)$$

From equations 1&2 $Px = Py = P_z$

OR




A
B
C
D