

Example (3-1)

A vacuum gage connected to a chamber reads 5.8 psi at a location where the atmospheric pressure is 14.5 psi. Determine the absolute pressure in the chamber.

SOLUTION:

$$\text{Absolute Pressure} = \text{Atmospheric Pressure} - \text{Vacuum Pressure}$$

$$= 14.7 - 5.8 = 8.9 \text{ psi}$$

Example (3-2)

A large storage tank contains oil having a density of 917 kg/m^3 . The tank is 3.66 m tall and vented (open) to the atmosphere of 1 atm at the top. The tank is filled with oil to a depth of 3.05 m (10 ft) and also contains 0.61 m (2 ft) of water in the bottom of the tank. Calculate the pressure in Pa and psia at 3.05 m from the top of the tank and at the bottom. And calculate the gauge pressure at the bottom of the tank.

Solution:

$$P_o = 1 \text{ atm} = 14.7 \text{ psia} = 1.01325 \times 10^5 \text{ Pa}$$

$$P_1 = h_1 \rho_{\text{oil}} g + P_o$$

$$= 3.05 \text{ m} (917 \text{ kg/m}^3) 9.81 \text{ m/s}^2 + 1.01325 \times 10^5 \text{ Pa}$$

$$= 1.28762 \times 10^5 \text{ Pa}$$

$$P_1 = 1.28762 \times 10^5 \text{ Pa} (14.7 \text{ psia} / 1.01325 \times 10^5 \text{ Pa})$$

$$= 18.675 \text{ psia}$$

$$P_2 = P_1 + h_2 \rho_{\text{water}} g$$

$$= 1.28762 \times 10^5 \text{ Pa} + 0.61 \text{ m} (1000 \text{ kg/m}^3) 9.81 \text{ m/s}^2$$

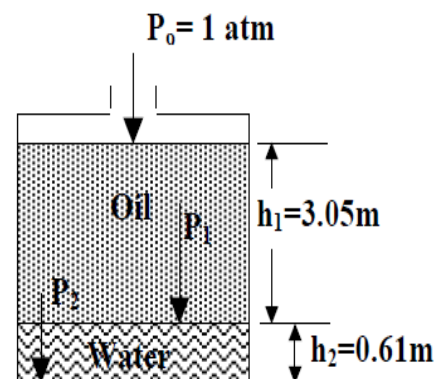
$$= 1.347461 \times 10^5 \text{ Pa}$$

$$P_2 = 1.347461 \times 10^5 \text{ Pa} (14.696 \text{ psia} / 1.01325 \times 10^5 \text{ Pa})$$

$$= 19.5433 \text{ psia}$$

$$\text{The gauge pressure} = P_{\text{abs}} - P_{\text{atm}}$$

$$= 19.5433 - 14.7 = 4.8433 \text{ psig}$$



Example (3-3)

A closed tank contains 0.5 m of mercury, 1.5 m of water, 2.5 m of oil of sp.gr. = 0.8 and air space above the oil. If the pressure at the bottom of the tank is 2.943 bar gauge, what should be the reading of mechanical gauge at the top of the tank.

Solution:

Pressure due to 0.5 m of mercury

$$P_m = 0.5 (13600) 9.81 = 0.66708 \text{ bar}$$

Pressure due to 1.5 m of water

$$P_w = 1.5 (1000) 9.81 = 0.14715 \text{ bar}$$

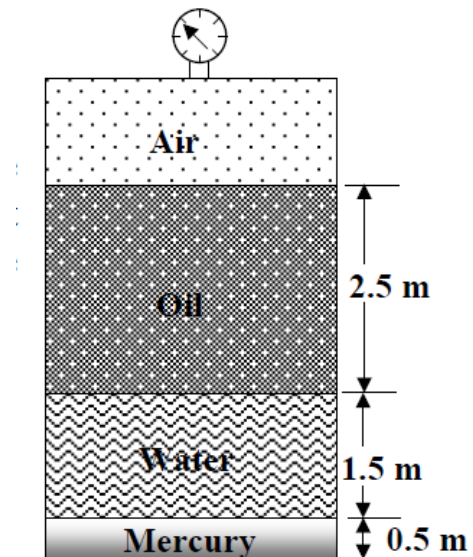
Pressure due to 2.5 m of oil

$$P_o = 2.5 (800) 9.81 = 0.19620 \text{ bar}$$

Pressure at the bottom of the tank = $P_m + P_w + P_o + P_{Air}$

$$\Rightarrow 2.943 = 0.66708 \text{ bar} + 0.14715 \text{ bar} + 0.19620 \text{ bar} + P_{Air}$$

$$\Rightarrow P_{Air} = 1.93257 \text{ bar}$$

**3.5 Measurement of Fluid Pressure**

In chemical and other industrial processing plants it is often to measure and control the pressure in vessel or process and/or the liquid level vessel.

The pressure measuring devices are:

1- Piezometer tube

The piezometer consist a tube open at one end to atmosphere, the other end is capable of being inserted into vessel or pipe of which pressure is to be measured. The height to which liquid rises up in the vertical tube gives the pressure head directly.

$$\text{i.e. } P = h \rho g$$

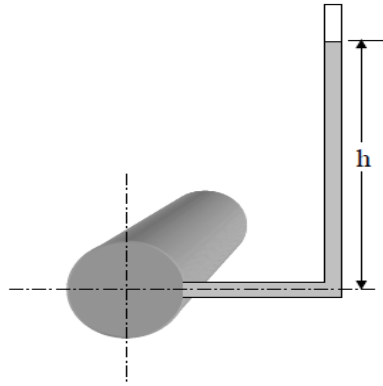


Figure (3-4) piezometer

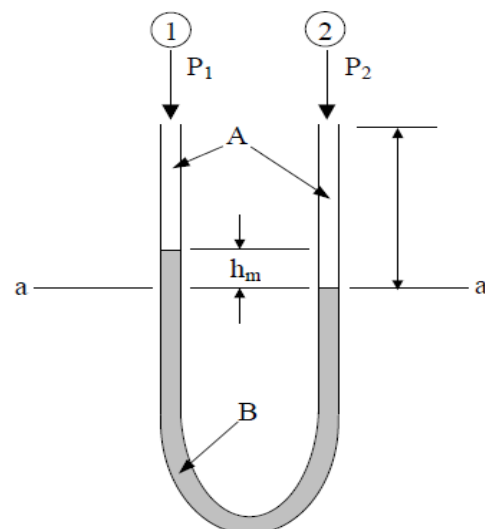
Piezometer is used for measuring moderate pressures. It is meant for measuring gauge pressure **only** as the end is open to atmosphere. It cannot be used for vacuum pressures.

2- Manometers

The manometer is an improved (modified) form of a piezometer. It can be used for measurement of comparatively *high pressures* and of both *gauge and vacuum pressures*.

Following are the various types of manometers: -

- a- Simple manometer
- b- The well type manometer
- c- Inclined manometer
- d- The inverted manometer
- e- The two-liquid manometer



a Simple manometer

It consists of a transparent U-tube containing the fluid A of density (ρ_A) whose pressure is to be measured and an immiscible fluid (B) of higher density (ρ_B). The limbs are connected to the two points between which the pressure difference ($P_2 - P_1$) is required; the connecting leads should be completely full of fluid A. If P_2 is greater than P_1 , the interface between the two liquids in limb (2) will be depressed a distance (h_m) (say) below that in limb (1).

The pressure at the level a — a must be the same in each of the limbs and, therefore:

$$P_2 + Z \rho_A g = P_1 + (Z - h_m) \rho_A g + h_m \rho_B g$$

$$\Rightarrow \Delta p = P_2 - P_1 = h_m (\rho_B - \rho_A) g$$

Figure (3-5): The simple manometer

If fluid A is a gas, the density ρ_A will

Normally be small compared with the density of the manometer fluid ρ_B so that:

$$\Delta p = P_2 - P_1 = h_m \rho_B g$$

b-The well-type manometer

In order to avoid the inconvenience of having to read two limbs and in order to measure low pressures where accuracy of much importance, the well-type manometer shown in Figure (3-6) can be used.

If A_w and A_c are the cross-sectional areas of the well and the column and h_m is the increase in the level of the column and h_w the decrease in the level of the well, then:

$$P_2 = P_1 + (h_m + h_w) \rho g$$

$$\text{or: } \Delta p = P_2 - P_1 = (h_m + h_w) \rho g$$

The quantity of liquid expelled from the well is equal to the quantity pushed into the column so that:

$$A_w h_w = A_c h_m \Rightarrow h_w = (A_c/A_w) h_m$$

$$\Rightarrow \Delta p = P_2 - P_1 = \rho g h_m (1 + A_c/A_w)$$

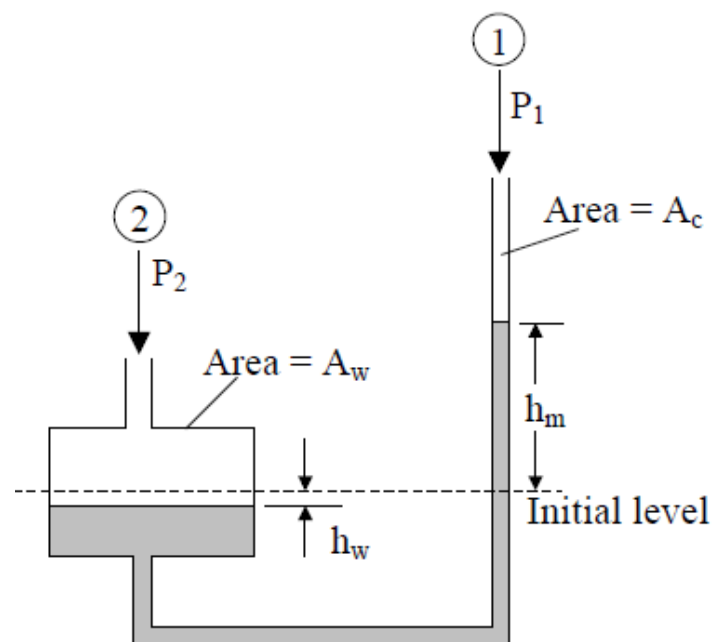


Figure (3-6): The well-type manometer

If the well is large in comparison to the column then:

$$\text{i.e. } (A_c/A_w) \rightarrow \approx 0 \Rightarrow \Delta p = P_2 - P_1 = \rho g h_m$$

c-The inclined manometer

Shown in Figure (3-7) enables the sensitivity of the manometers described previously to be increased by measuring the length of the column of liquid. If θ is the angle of inclination of the manometer (typically about $10\text{-}20^\circ$) and L is the movement of the column of liquid along the limb, then: $h_m = L \sin \theta$

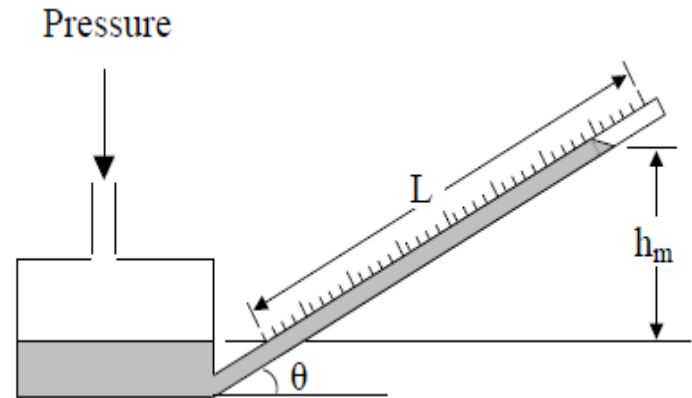


Figure (3-7): The inclined manometer

If $\theta = 10^\circ$, the manometer reading L is increased by about 5.7 times compared with the reading h_m which would have been obtained from a simple manometer.

d-The inverted manometer

Figure (3-8) is used for measuring pressure differences in liquids. The space above the liquid in the manometer is filled with air, which can be admitted or expelled through the tap A in order to adjust the level of the liquid in the manometer.

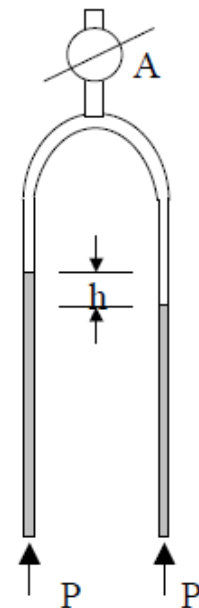


Figure (3-8): The inverted manometer