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 consists 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.

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

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*.

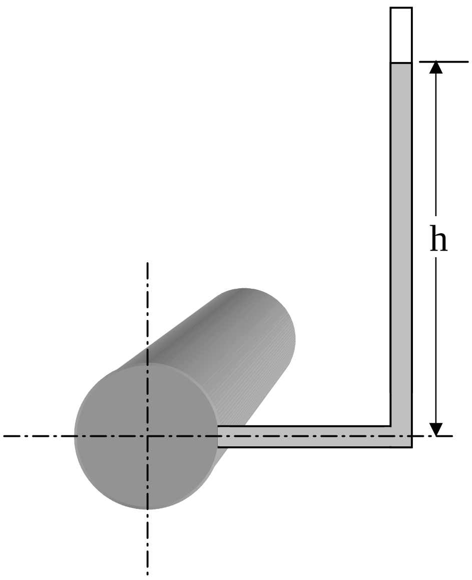


Figure (3): The Piezometer

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.

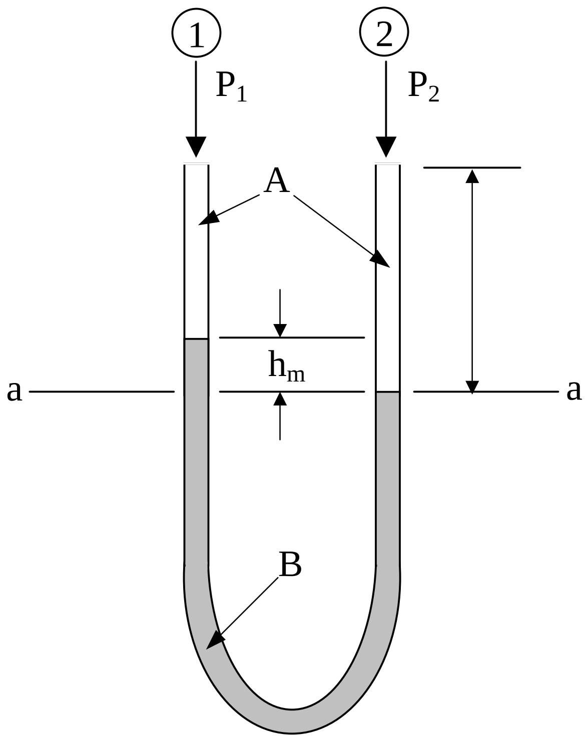


Figure (4): The simple manometer

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

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

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

If fluid A is a gas, the density ρ_A will normally be small compared with the density of the manometer fluid pm 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 id of much importance, the well-type manometer shown in Figure (5) 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:

$$P_2 = P1 + (h_m + h_w) \rho g$$

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

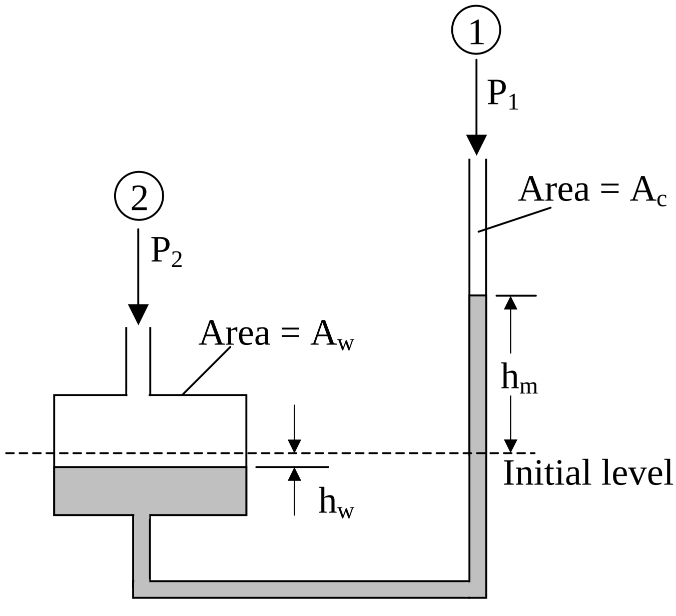


Figure (5): The well-type manometer

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

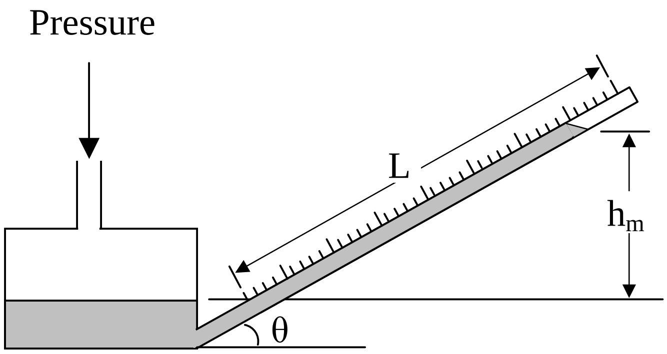
$$A_w h_w = A_c h_m \Rightarrow h_w = (A_c/A_w) h_m$$

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

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

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

c- The inclined manometer



Shown in Figure (6) 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 10-20°) and L is the movement of the column of liquid along the limb, then:

$$h_m = L \sin\theta$$

Figure (6): The inclined manometer

If θ = 10°, 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 (7) 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.

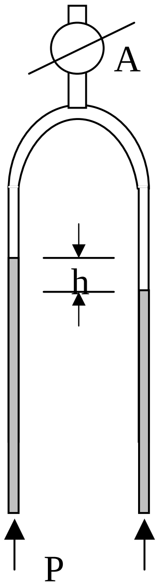


Figure (6): The inverted manometer

e- The two-liquid manometer

Small differences in pressure in gases are often measured with a manometer of the form shown in Figure 6.5. The reservoir at the top of each limb is of a sufficiently large cross-section for the liquid level to remain approximately the on each side of the manometer.

The difference in pressure is then given by:

$$\Delta p = P_2 - P_1 = h_m (\rho_{m1} - \rho_{m2})\, g$$

where ρ_{m1} and ρm2 are the densities of the two manometer liquids. The sensitivity of the instrument is very high if the densities of the two liquids are nearly the same. To obtain accurate readings it is necessary to choose liquids, which give sharp interfaces: paraffin oil and industrial alcohol are commonly used.

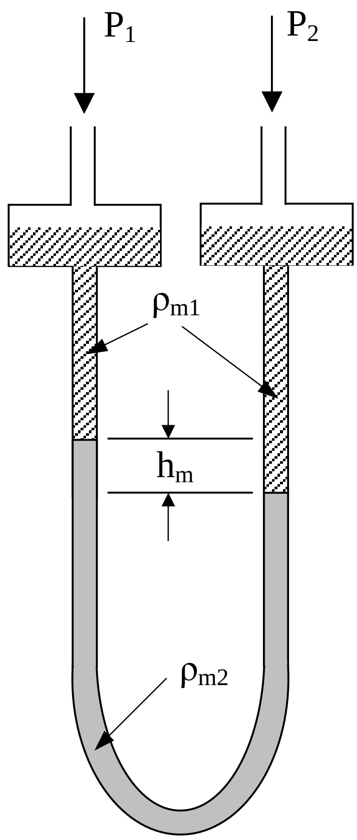


Figure (7): The two-liquid manometer

3- Mechanical Gauges

Whenever a *very high fluid pressure* is to be measured, and a *very great sensitivity* a mechanical gauge is best suited for these purposes. They are also designed to read vacuum pressure. A mechanical gauge is also used for measurement of pressure in boilers or other pipes, where tube manometer cannot be conveniently used.

There are many types of gauge available in the market. But the principle on which all these gauge work is almost the same. The followings are some of the important types of mechanical gauges: -

1- The Bourdon gauge
2- Diaphragm pressure gauge
3- Dead weight pressure gauge

The Bourdon gauge

The pressure to be measured is applied to a curved tube, oval in cross-section, and the deflection of the end of the tube is communicated through a system of levers to a recording needle. This gauge is widely used for *steam* and *compressed gases*, and frequently *forms the indicating element on flow controllers*. The simple form of the gauge is illustrated in Figures (7a) and (7b). Figure (7c) shows a Bourdon type gauge with the sensing element in the form of a helix; this instrument has a very much greater sensitivity and is suitable for very high pressures.

It may be noted that the pressure measuring devices of category (2) all measure a pressure difference ($\Delta p = P_2 - P_1$). In the case of the Bourdon gauge (1) of category (3), the pressure indicated is the difference between that communicated by the system to the tube and the external (ambient) pressure, and this is usually referred to as *the gauge pressure*. It is then necessary to add on the ambient pressure in order to obtain the *(absolute) pressure*.

Figure (7) Bourdon gauge

Gauge pressures are not, however, used in the SI System of units.