[Measurement of Pressure]

Pressure is defined as force acting per unit area. It is generally measured in N/m^2. There are a number of other units to measure pressure e.g. pascal, bar, torr, atm etc.

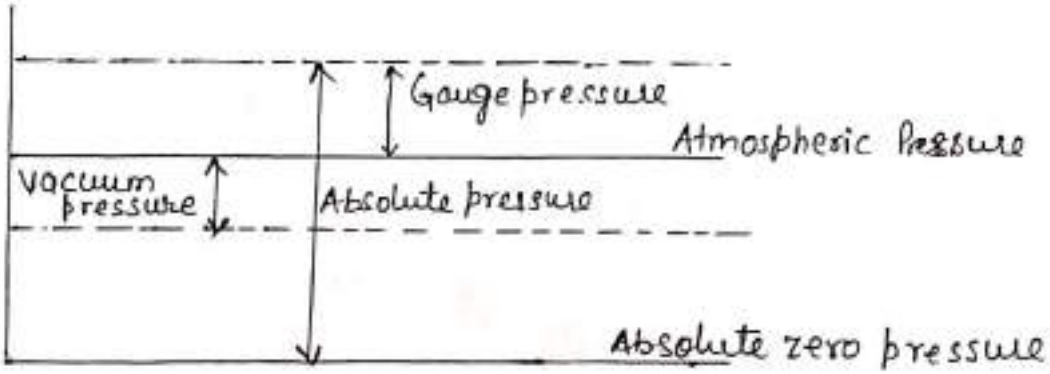
1 Pascal = 1 N/m^2
1 bar = 10^5 N/m^2
1 torr = 1 mm of Hg
1 atm = 760 mm of Hg

Pressure exerted by air envelope surrounding the earth surface is called <u>atmospheric pressure</u>.

In pressure measuring instruments, pressure is usually measured as difference between unknown pressure and atmospheric pressure. This difference is known as <u>gauge pressure</u>.

Pressure measured with respect to perfect vacuum (i.e. absolute zero pressure) is known as <u>absolute pressure</u>.

Pressure less than atmospheric pressure is known as <u>vacuum or negative pressure</u>.



From above figure, Absolute pressure = Atmospheric pressure + Gauge Pressure

Pressure Measuring Instruments :

Pressure Measuring Instruments

- Low Pressure Measuring Instruments
  1. Pirani Gauge
  2. Ionization Gauge
  3. Mc Leod Gauge
  4. Knudsen Gauge
- Moderate Pressure Measuring Instruments
  1. Elastic Elements
  2. Manometers
- High Pressure Measuring Instruments
  1. High Pressure Transducers.

* Low Pressure Measuring Instruments are used for measuring the pressure less than 1 mm Hg.
* High Pressure Measuring Instruments are used for measuring pressure above 100 atm.

Pirani Gauge :

It is also known as thermal conductivity Gauge. It is based on the principle that the temp. of a current carrying conductor will not only depend upon the magnitude of current and the resistivity of conductor but also on rate at which heat is dissipated. The rate of heat dissipation depends upon the conductivity of the surrounding gases. With drop in pressure the density of gases surrounding the current carrying conductor decreases, which in turn reduces the rate of heat dissipation and results in rise of the temp. of the conducting wire.

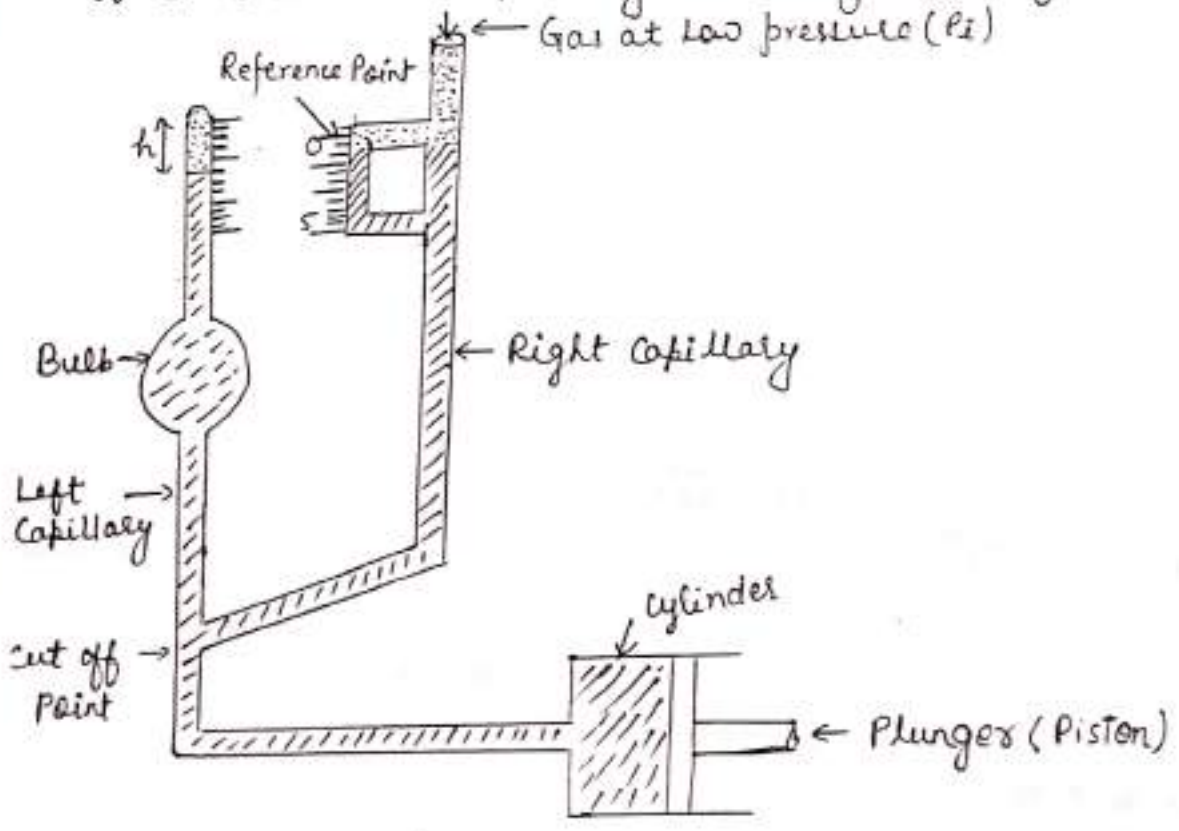
Pirani gauge basically consists of thin platinum wire enclosed in a chamber as shown in figure.

(Pirani Gauge)

With reduction in pressure of the gas surrounding the platinum filament, the rate of heat dissipation reduces. This results in rise in temperature of filament and hence its resistance changes. The change in resistance of the filament corresponds to change in pressure.

Mcleod Gauge :

It is used to measure vacuum pressure in the range of 0.01 to 1000 microns.
It works on the principle that a known volume of gas whose pressure is to be measured is trapped and then compressed isothermally by rising mercury column. Mcleod gauge consists of capillary tubes connected to a mercury (Hg) reservoir. The piston can be moved to and fro to fill or evacuate the capillary tubes of mercury.



(Mcleod Gauge)

To measure the pressure of the gas, the plunger is first moved to the right till the Hg level falls below the cut off point. This allows the gas from the right capillary to fill the left capillary and bulb. Now the plunger is moved to left so that the Hg rises in the capillary tubes. As soon as Hg rises above cut off point, a known volume of gas gets trapped in the bulb and left capillary. Now plunger is moved left till the 'Hg' rises to reference point (zero), in the right capillary.

Let initial pressure and volume of the gas in the left capillary and bulb before being trapped by 'Hg' column be P_i and V_i respectively.

Let final pressure and volume of gas trapped in the left capillary after being compressed by rising Hg column be P_f and V_f respectively.

Then According to Boyle's Law,

$$P_i V_i = P_f V_f$$

But $P_f = P_i + h$

and $V_f = a \times h$

where $a \rightarrow$ area of cross section of capillary.

Hence $P_i V_i = (P_i + h) a h$

$$\Rightarrow P_i V_i - P_i a h = a h^2$$

$$\Rightarrow P_i (V_i - ah) = ah^2$$

$$\text{or } P_i = \frac{ah^2}{(V_i - ah)}$$

Manometer :

It is an instrument used for measuring the pressure at a point in a fluid by balancing the column of fluid by same or another fluid column.

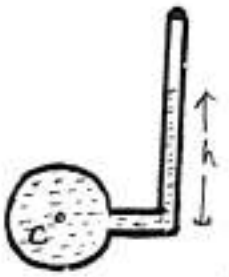
- Manometer
  - Simple Manometers
    1. Piezometer
    2. U- tube manometer
    3. Single column Manometer
  - Differential Manometers
    1. U-tube differential manometer
    2. Inverted U-tube differential manometer

Piezometer :

It is the simplest type of manometer. The device consists of a glass tube connected to pipe at point where the fluid pressure is to be measured. If 'h' is height of liquid column in the tube, then pressure is given by

$$p = h\rho g$$

where ρ is density of liquid.



(Piezometer)

U- tube Manometer :

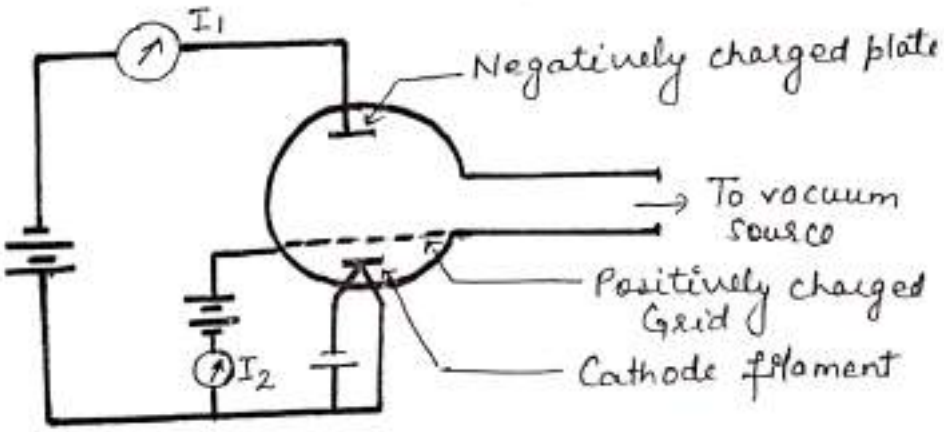
It is a U-shaped glass tube. One end of the U-tube is connected to the point where pressure is to be measured while the other end remains open to the atmosphere. The U-tube generally contains mercury but can make use of any liquid whose specific gravity is greater than that of liquid

Ionization Gauge : It is a device for measuring low pressure. It consists of a vacuum tube connected to the vacuum source. A negatively charged plate, positively charged grid and a cathode filament are arranged in the electric circuit as shown in figure. Electrons emitted by the hot cathode filament are attracted by the positively charged grid. In their passage, the electrons collide with the gas molecules and ionise them into anions and cations. The positively charged cations move towards the negatively charged plate thus producing current I_1', while the electrons emitted by filament move towards the grid producing current I_2'.

Experimentally it has been found that the pressure of the gas in the vacuum tube is given by the relation,

$$P = \frac{I_1}{\alpha I_2}$$

where α is known as sensitivity of the gauge.



[Schematic diagram of ionization Gauge]

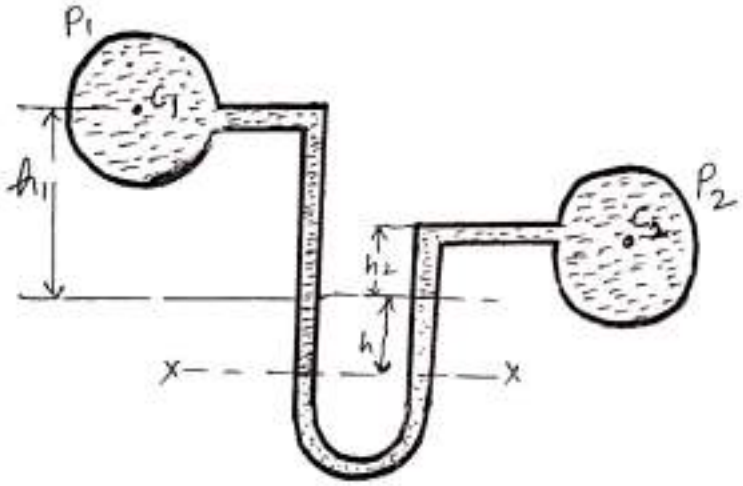
Moderate pressure Measuring Instruments :

For measuring moderate pressures, manometers and elastic elements can be used.

Differential Manometer :

These are used for measuring the difference of pressures between two points in a pipe or between two seperate points.

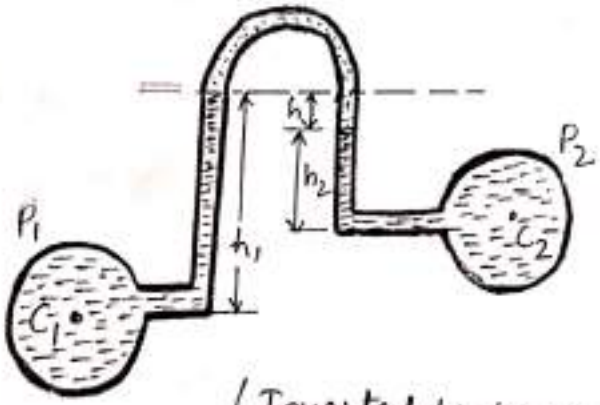
It consists of U-tube, containing heavy liquid, whose ends are connected to the points whose pressure difference is to be measured.



(U-tube differential manometer)

If S is specific gravity of Mercury (Hg) in the U-tube, S_1 and S_2 are specific gravities of liquids in pipes P_1 and P_2, then the difference in pressure heads of pipes P_1 and P_2,

$$h_{C_1} - h_{C_2} = h(S - S_1) + h_2 S_2 - h_1 S_1$$



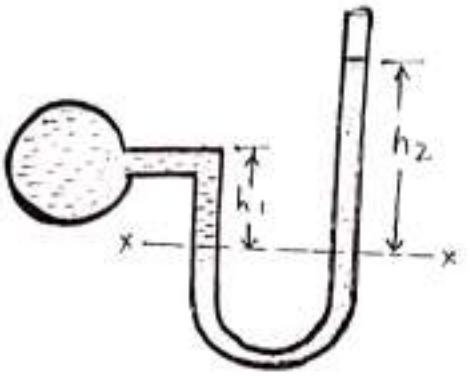
$$\Rightarrow h_{C_1} - h_{C_2} = h_1 S_1 - h_2 S_2 - hS$$

(Inverted U-tube differential manometer)

whose pressure is being measured.

Let S_1 and S_2 is the specific gravity of light and heavy liquid then pressure head of liquid at point 'C' is given by,

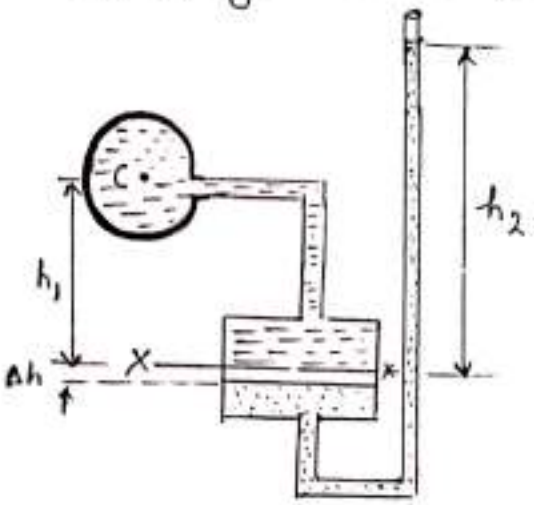
$$h = h_2 S_2 - h_1 S_1$$



(U- tube manometer)

Single Column Manometer :

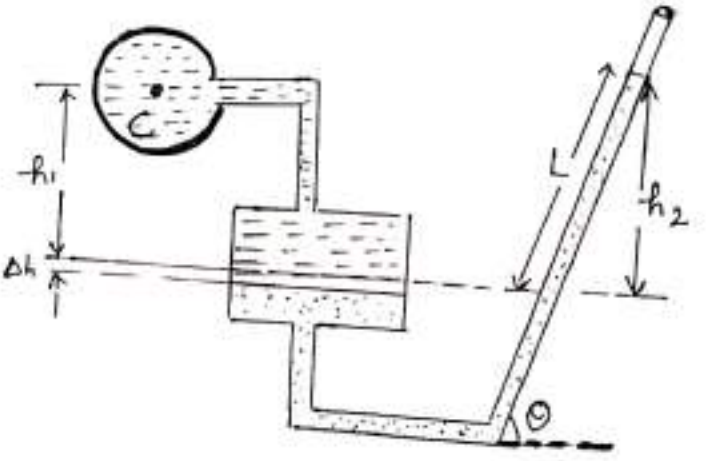
These are of two types : vertical single column manometer and inclined single column manometer. These have large reservoir. Even for small change in pressure, the level of Hg in reservoir will have small change but in the right limb the change will be appreciable. These are more sensitive.



(Vertical Single column manometer)

The pressure head at point 'C'

$$h_C = h_2 S_2 - h_1 S_1$$



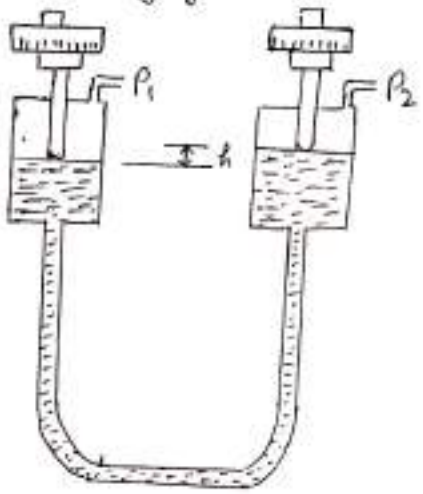
(Inclined Single column manometer)

The pressure head at point 'C'

$$h_C = L \sin\theta\, S_2 - h_1 S_1$$

Micromanometer :

Micromanometer is used to increase the accuracy of reading of the manometer. Even very small change in liquid level can be easily detected by using the micrometer heads as shown in figure.

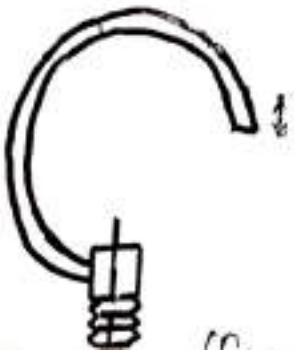


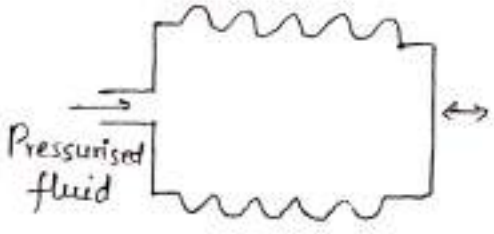
(Micromanometer)

Elastic Elements :

Different type of elastic elements are used to design and manufacture of pressure measuring instruments. Examples of such elements are Bourdon tube, bellows, capsule and expandable helical tube.

When the pressurised fluid enters the elastic element, its free end moves. This motion can be transferred to the pointer which gets deflected to show reading on the scale. Bourdon tube pressure gauge makes use of Bourdon tube and an LVDT type pressure transducer makes use of bellows.

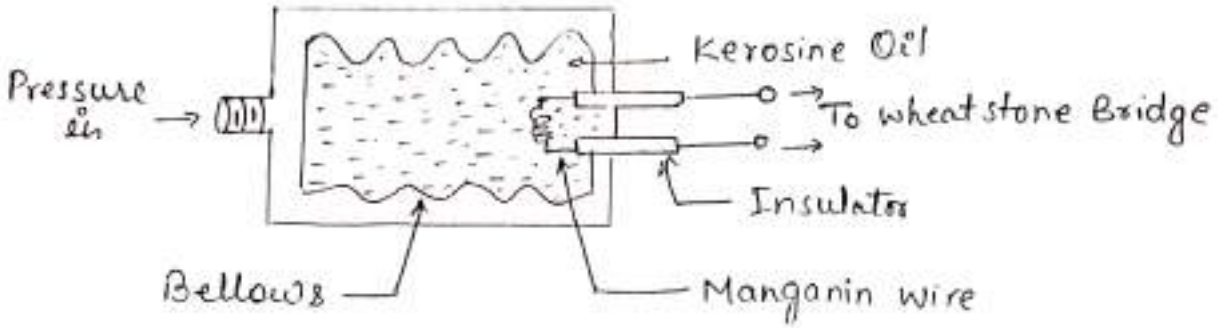




(Bellows)

High Pressure Measuring Instruments :

For high pressure measurement, high pressure transducer is used. It consists of a wire of Manganin (Cu, Ni and Mn alloy) enclosed in bellows. The bellows are filled with kerosine to transfer pressure to the wire. Due to pressure resistance of wire changes. The change in resistance can be measured by wheat stone bridge. Wheatstone bridge can also be directly calibrated in terms of pressure applied.

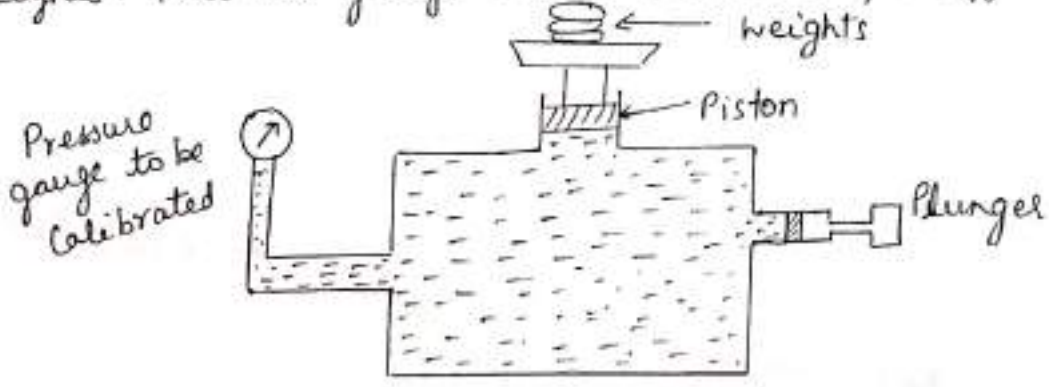


(High pressure transducer)

Calibration of Pressure Measuring Instruments :

The calibration of moderate pressure measuring instrument is done with dead weight tester.

The plunger is pushed in to build sufficient pressure in tester till the weights just seem to be lifted upwards. At this point fluid gauge pressure is equal to pressure exerted by dead weights. Thus the gauge can be calibrated for different weights.



(Dead Weight Tester)