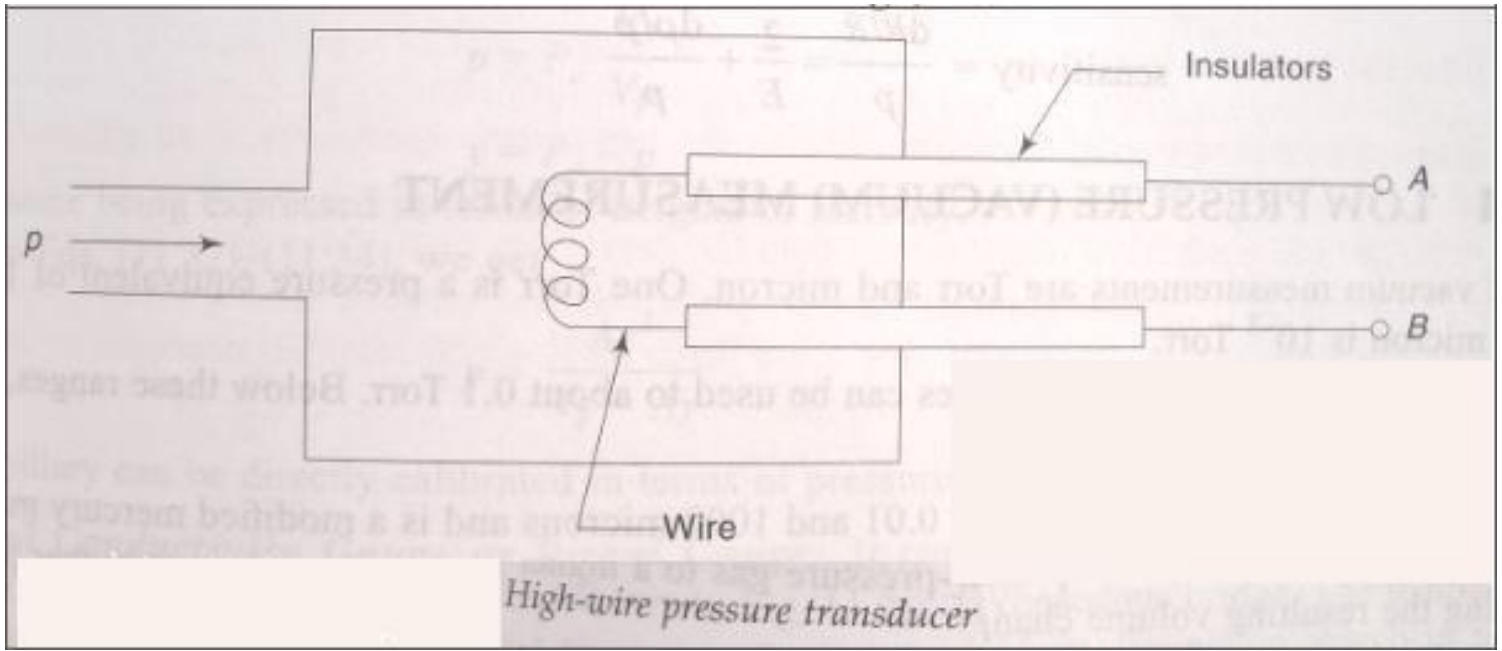
High Pressure Measurement

- Pressures above 1000 atm.
- The technique is based on the electrical resistance change of a manganin (alloy of Cu, Ni, Mn) 0r gold chrome wire, with hydrostatic pressure, due to bulk compression effect.
- Coil is enclosed in a flexible bellows filled with kerosene, for transmitting the pressure to be measured to the coil.
- Change in resistance of wire is measured by usual methods like Wheatstone bridge, etc.



High-wire pressure transducer

- sensitivity for manganin, is 2.5 x 10^{-11} Ω/Ω-Pa and for gold-chrome 9.85 x 10^{-12} Ω/Ω-Pa.
- Gold-chrome is preferred since it is less temperature sensitive.

- Expression for Sensitivity: for a wire of diameter D, length L, Poisson's ratio v and Young's modulus E, the resistance will be,

$$R = \frac{4\rho L}{\pi D^2}$$

ρ being resistivity constant. From the above, we can write

$$\frac{dR}{R} = \frac{dL}{L} - \frac{2\,dD}{D} + \frac{d\rho}{\rho} \qquad \text{(equation-1)}$$

Relations between strains ε_x, ε_y and ε_z in the three perpendicular directions, in terms of stresses σ_x, σ_y and σ_z are

$$\varepsilon_x = \frac{1}{E}\,[\sigma_x - \nu(\sigma_y + \sigma_z)]$$

$$\varepsilon_y = \frac{1}{E}\,[\sigma_y - \nu(\sigma_x + \sigma_z)] \qquad \text{(equations - 2)}$$

$$\varepsilon_z = \frac{1}{E}\,[\sigma_z - \nu(\sigma_x + \sigma_y)]$$

Thus, taking $\sigma_x = \sigma_y = -p$ and $\sigma_z = 0$ we get from Eq. (.2)

$$\varepsilon_x = \varepsilon_y = \frac{dD}{D} = -\frac{p}{E}(1 - \nu)$$

$$\varepsilon_z = \frac{dL}{L} = \frac{2\nu p}{E}$$

Substituting in Eq. (1)

$$\frac{dR}{R} = \frac{2p}{E} + \frac{d\rho}{\rho}$$

Thus,

$$\text{sensitivity} = \frac{dR/R}{p} = \frac{2}{E} + \frac{d\rho/\rho}{p}$$

Low Pressure (Vacuum) Measurement

- Units of vacuum measurement are Torr and micron.
- One Torr = 1 mm of Hg.
- One micron = 10^{-3} Torr.
- Up to 0.1 Torr manometer & elastic element gauges are used
- Below 0.1 Torr vacuum gauges are used.

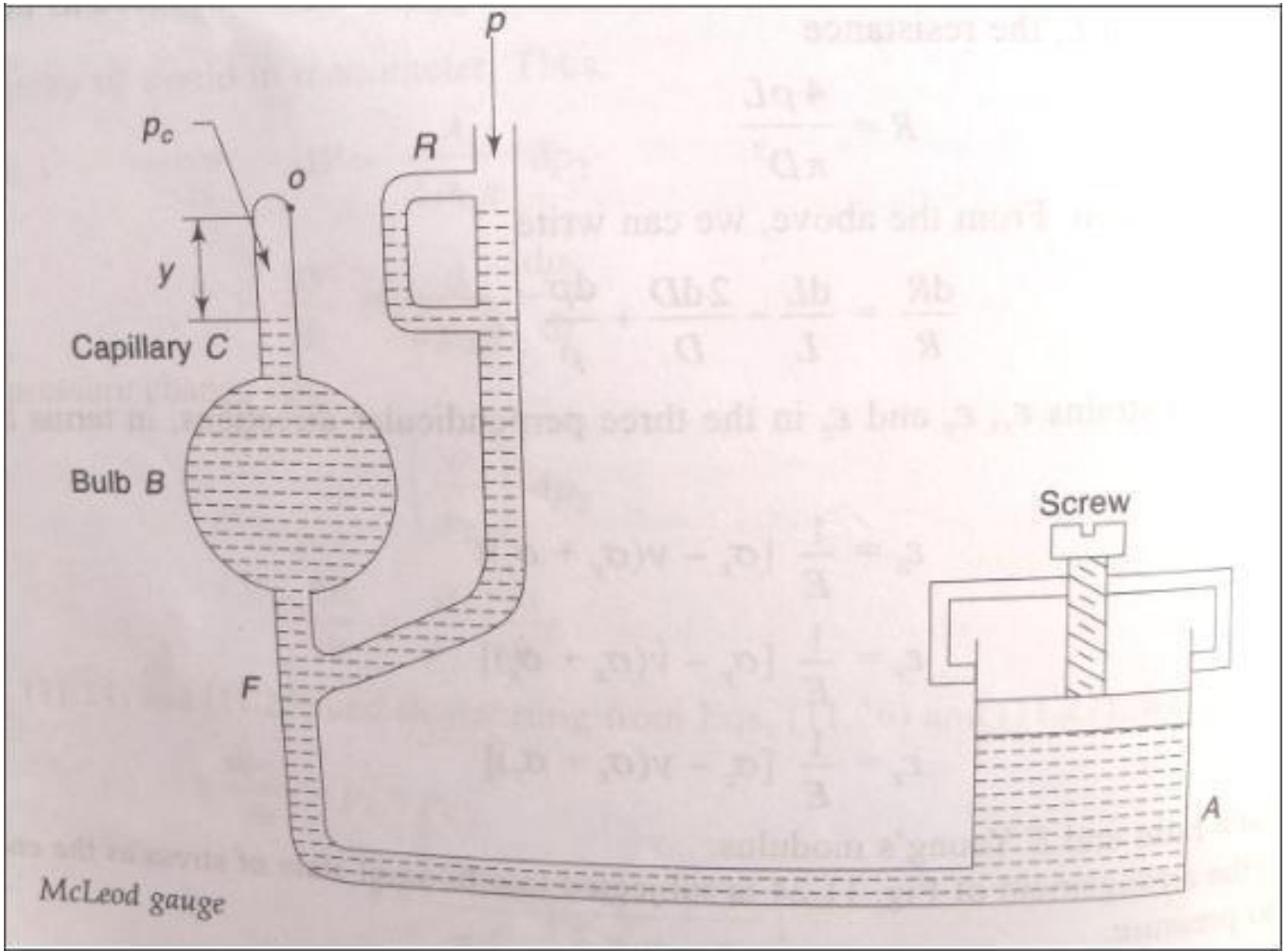
McLeod Gauge

- Used for pressure between 0.01 – 1000 microns.
- Modified mercury manometer.
- Operates on the principle of compressing a known volume of low-pressure gas to a higher pressure and measuring the resulting volume change.

Steps of measuring pressure:

1. Unknown pressure source is connected to gauge and mercury level is adjusted so that pressure source fills the bulb B and capillary C.
2. Mercury is forced from reservoir A to the bulb & reference column R.
3. At cut-off point F, a known volume of gas is trapped in the bulb and capillary.

- The mercury level is raised till it reaches the zero reference point O in R.
- The difference in heights is measured as y.
- Thus y is a measure of pressure p.



If p = unknown pressure
A = area of cross-section of capillary
V_c = Volume of gas in capillary
$= Ay$
P_c = pressure of gas in the capillary c after compression
V_F = volume of capillary and bulb till F

then,

$$p = P_c \frac{V_c}{V_F}$$

where $$y = P_c - p$$

the pressure being expressed in terms of heights of mercury.

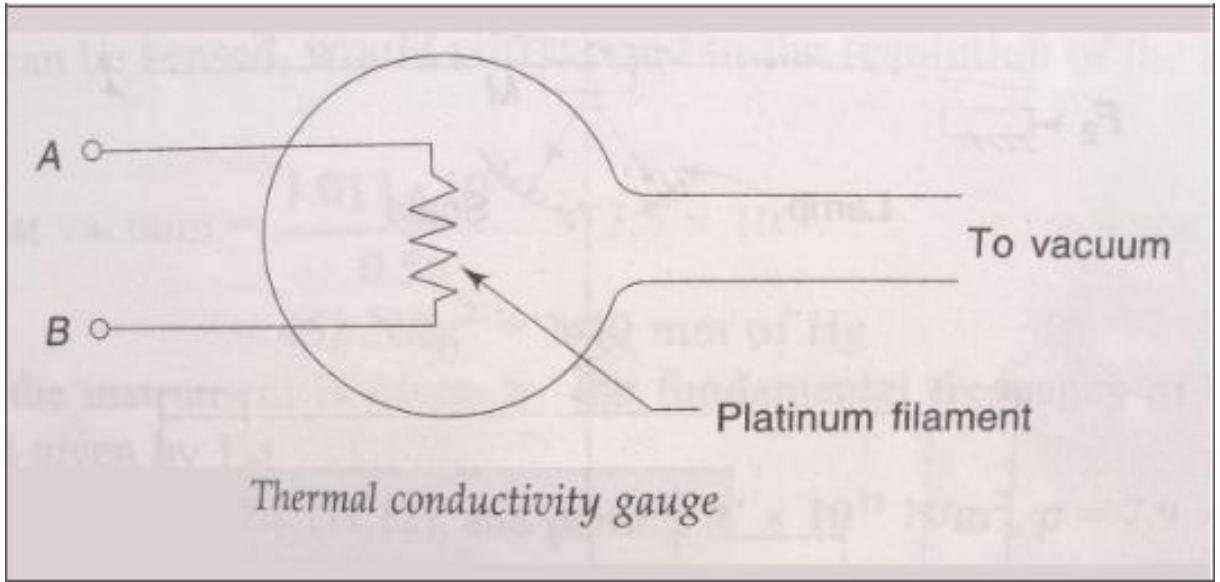
From Eqs. (11.32)–(11.34), we get

$$p = \frac{Ay^2}{V_F - Ay}$$

The capillary can be directly calibrated in terms of pressure p.

Thermal Conductivity Gauge / Pirani Gauge.

- Consists Platinum filament enclosed in a chamber.
- The temperature of wire, for a given magnitude of current, depends on the rate of heat dissipation, which in turn depends on the conductivity of surrounding medium and hence its pressure.
- Thus change in pressure will change temperature and resistance of wire.
- This can be measured by using Wheatstone bridge.

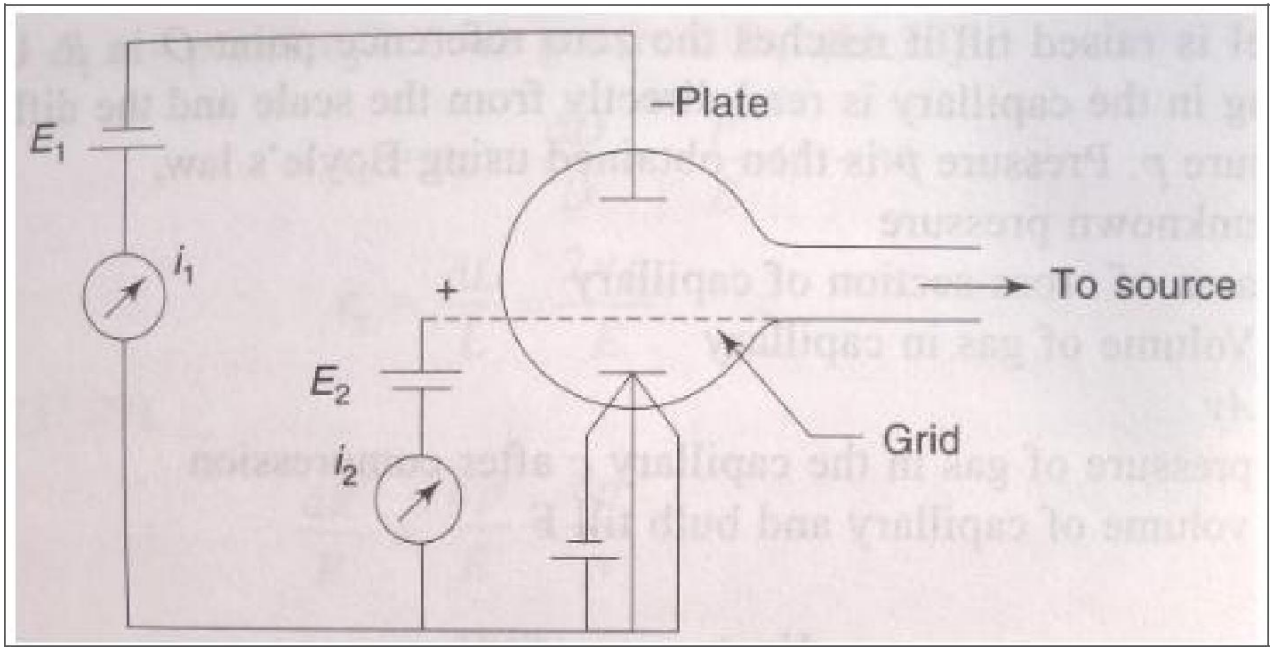


Thermal conductivity gauge

Ionisation Gauge

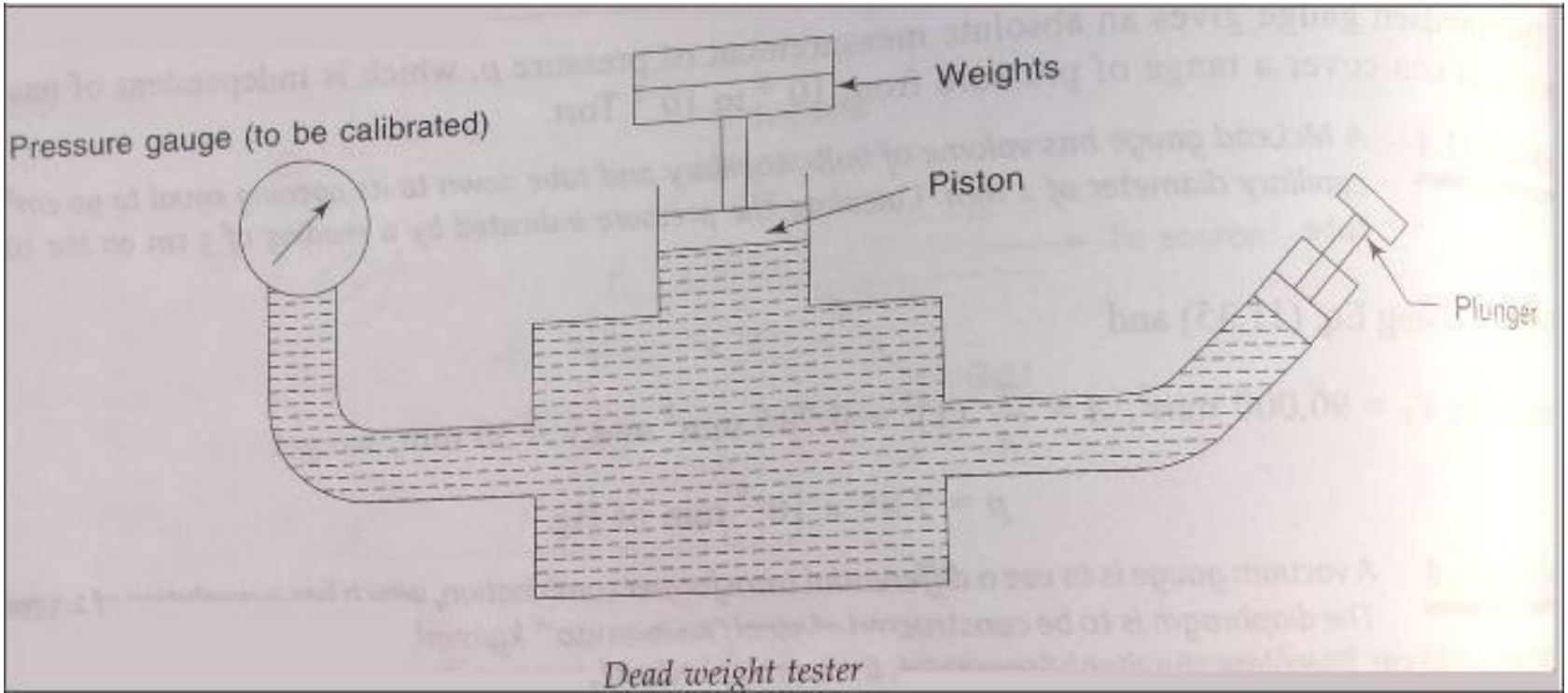
- Used to measure very low pressures of 1 micron and below.
- The gauge consists of a triode vacuum tube.
- Heated cathode emits electrons which are accelerated by positively charged grid.
- Electrons moving towards grid, ionize the gas molecules through collisions.
- Plate collects positive ions and produce a plate current i_i.
- Electrons & negative ions are collected by grid and produce grid current i_2.
- If k is sensitivity of gauge , then pressure of gas P will be,

$$p = \frac{1}{K}\frac{i_1}{i_2}$$



Calibration and Testing

- For static calibration of pressure, dead weight tester is used.
- The pressure in tester is built up till weights are seen to float, when the fluid pressure equals the dead weight divided by the piston area.
- Manometers can be used for calibration of moderate pressure measuring instruments.
- For low pressures, McLeod gauge can be used.



Dead weight tester