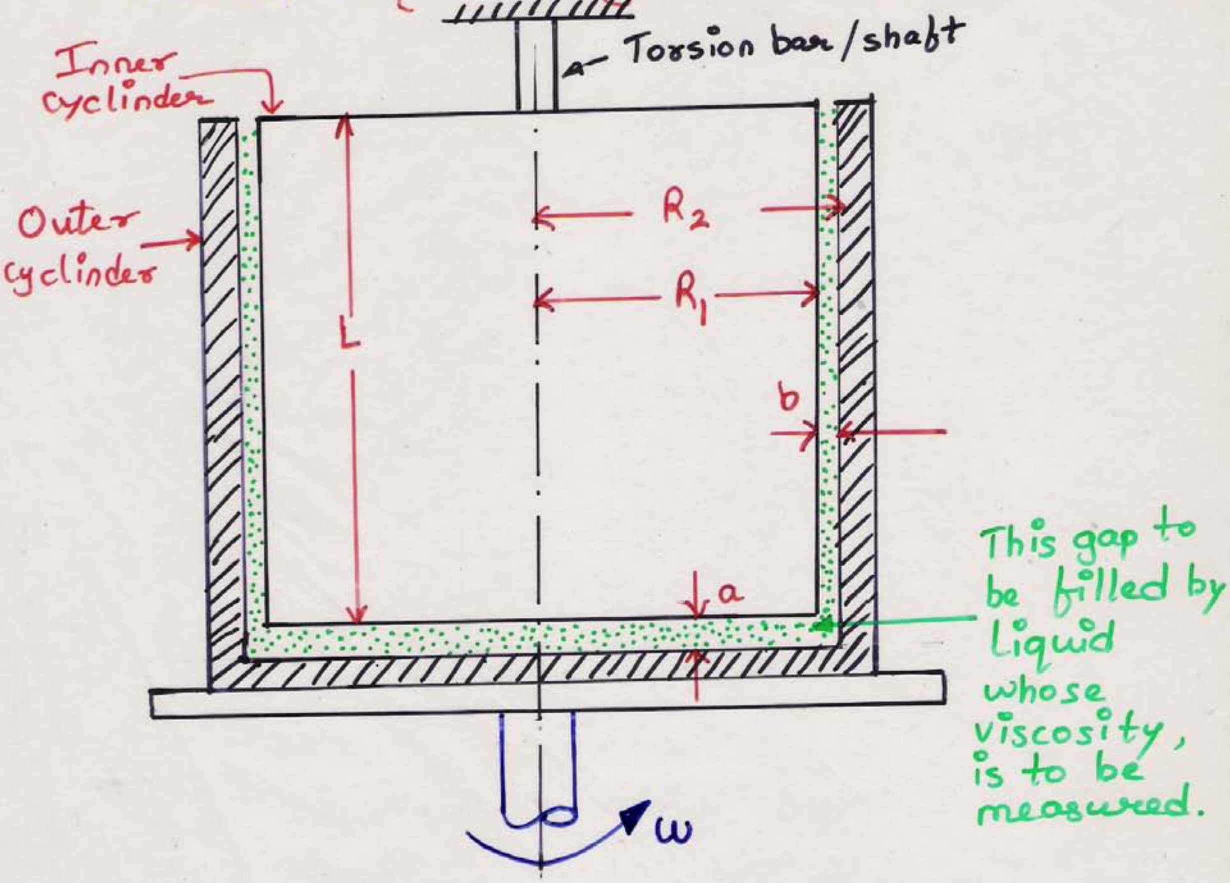
Measurement of Viscosity :-

1. Rotating Concentric Cylinder type Viscometer (Viscosity-to-Torque Converter)



Theory :-

- Development of torque (T) proportional to the viscosity (μ) of a liquid at varying velocities is possible here by using two vertical concentric cyclinders, one rotating and the other inner one kept static, separated by a small gap.

- Inner cyclinder is kept stationary and attached to a 'torque-measuring devices' or (torque transducer).
- The torque experienced by inner cyclinder is due to the rotation of outer cyclinder which is measured by a torque transducer.
- Outer cyclinder is driven by a motor at a constant angular velocity ω.
- It is essential, to keep the radius of inner cyclinder much larger than the gap between the outer and inner cyclinder.
- Dynamic Viscosity (μ) is given by

$$\boxed{\mu = \frac{T}{\pi \omega R_1^2 \left[\frac{R_1^2}{2a} + \frac{2LR_2}{b}\right]}} \quad ----(1)$$

where, T = torque experienced by inner cyclinder.
ω = angular velocity of outer cyclinder.
R_1, R_2, a, b = Dimensions & spacing's of two cyclinders.

- If torque (T), angular velocity (ω) & dimensions of cyclinder are measured, viscosity may be calculated as from equatn (1).
- Main advantage of rotational as compared to many other viscometers is its ability to operate continuously at a given shear rate, so that other steady-state measurements can be conveniently performed.

Capillary flow Method

- In this method, the pressure differences is measured across a capillary tube in which the liquid is flowing in 'LAMINAR FASHION.'

- It is based on fully developed Laminar flow theory (Hagen-Poiseuille flow)

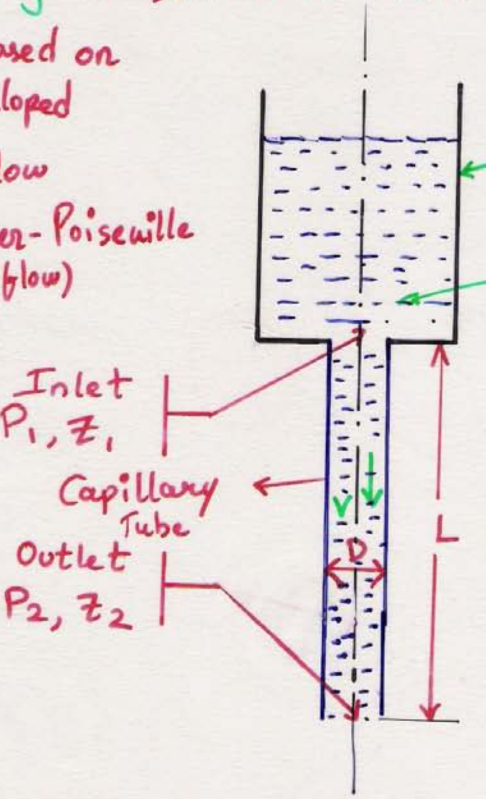


figure:- Capillary Viscometer

$\Delta P = P_1 - P_2$

- In Capillary Viscometer, the capillary tube length is many times larger than its small diameter ie $L >> D$.

- Consider the tube cross-section shown below

- If laminar flow exists in tube, parabolic-velocity profile will be experienced. as shown in diagram.

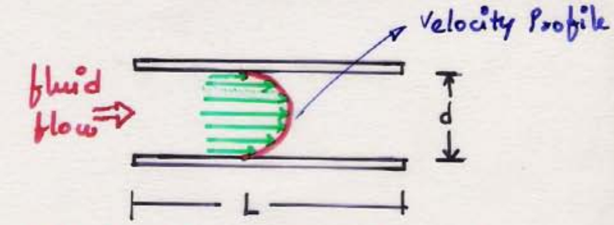


fig: Laminar flow through Capillary tube.

• Orifice-type / Short Capillary : Saybolt Viscometer

(Viscosity-to-Pressure Converter)

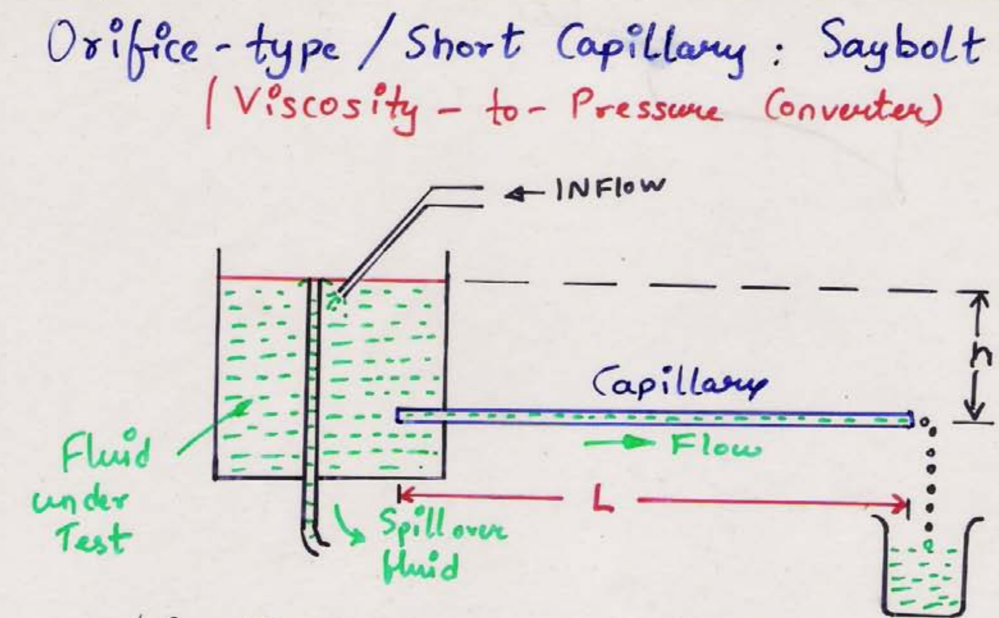


fig: Measurement of Viscosity of a liquid

- It is based on principle of measuring the pressure drop in laminar flow through a capillary tube.
- They are, in general, known as 'orifice-type viscometer' and are available as Saybolt Viscometers.
- When the flow through the capillary tube is established as shown in figure, it is necessary to calculate the volume flow-rate (Q) by measuring the volume of liquid collected in a certain time interval.
- The pressure difference across the capillary ΔP is taken as $h\rho g$, and the dynamic viscosity is calculated from 'Hagen-Poissuille' equatn.

$$\boxed{\mu = \frac{\pi d^4 \Delta P}{128 Q L}}$$

where, Q = Volume flow rate of fluid

L = length of Capillary tube.

- For accurate measurements, ΔP may be taken by measuring $(P_1 - P_2)$.
- For continuous viscosity measurements of a fluid, it is essential that a constant flow rate is maintained through the capillary tube by means of a constant flow pump and the pressure drop across the tube is continuously measured by a Pressure transducer, while the temperature is held constant.
- When fluid is a compressible gas, the temperature of the gas and the gas constant come into the picture.

∴ The dynamic viscosity of gas at absolute temperature T is obtained by

$$\mu = \frac{\pi R^4 (P_1^2 - P_2^2)}{16 \omega R_g T}$$

where, P_1 & P_2 are the pressures at two ends of capillary tubes, R_g is gas constant, and T is temperature.

- Due to their simplicity, reliability, and low cost, these viscometers are widely used for Newtonian fluids like in oil and other industries
- However, these viscometer are not suitable for absolute viscosity measurements, nor for Non-Newtonian fluids.

4. Variable Area type Viscometer:-

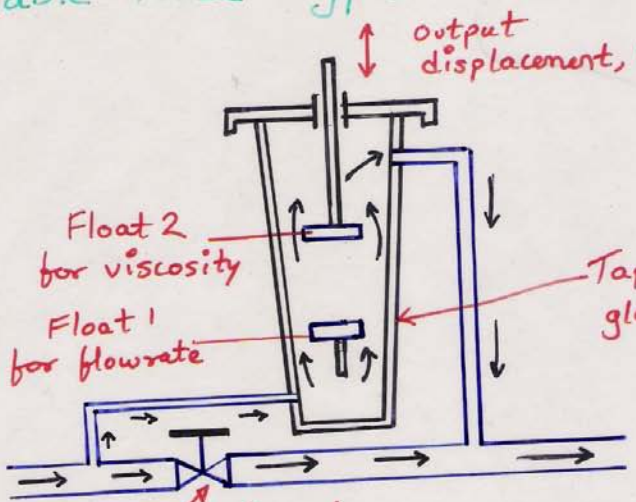


fig: Variable Area type Viscometer for Measurement of viscosity of fluids

- It utilizes a float specially designed such that its position varies with viscosity of the fluid, while the flow rate of fluid is held constant.
- Floats 1 and 2 are kept inside a tapered glass tube
- Float 1 is designed to be insensitive to viscosity and it's position determines the flow-rate only.
- Float 2 is sensitive to viscosity and its position is measured by a 'displacement transducer.'
- The throttling valve sets up a constant pressure difference across the meter and the constant flow rate is indicated by position of float 1.
- The system enables the measurement of viscosity of both liquid and gases.
- It has to be calibrated for each fluid and is suitable for 'Continuous monitoring of the Viscosity of the fluid'.