LIQUID DEVICES

1. Pitot Tube for Flow Measurement

- The humblest of devices for measuring flow velocity directly is the Pitot tube.
- **Construction**: The principle of flow measurement by Pitot tube was adopted first by a French Scientist Henri Pitot in 1732 for measuring velocities in the river. A right angled glass tube, large enough for capillary effects to be negligible, is used for the purpose. One end of the tube faces the flow while the other end is open to the atmosphere as shown in Fig. 1.a.

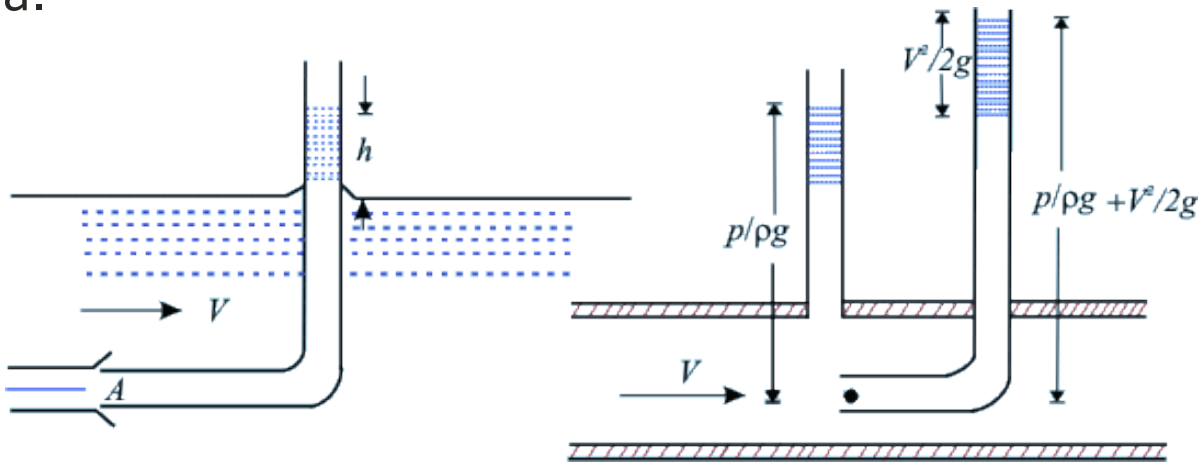


Fig 1. Simple Pitot Tube (a) tube for measuring the Stagnation Pressure;
(b) Static and Stagnation tubes together.

1. PITOT TUBE FOR FLOW MEASUREMENT

Working: The liquid flows up the tube and when equilibrium is attained, the liquid reaches a height above the free surface of the water stream.

Since the static pressure, under this situation, is equal to the hydrostatic pressure due to its depth below the free surface, the difference in level between the liquid in the glass tube and the free surface becomes the measure of dynamic pressure. Therefore, we can write, neglecting friction,

$$p_0 - p = \frac{\rho V^2}{2} = h\rho g$$

where p_o, p and V are the stagnation pressure, static pressure and velocity respectively at point A (Fig. 1).

$$V = \sqrt{2gh}$$

Such a tube is known as a Pitot tube and provides one of the most accurate means of measuring the fluid velocity.

1. PITOT TUBE FOR FLOW MEASUREMENT

- For an open stream of liquid with a free surface, this single tube is sufficient to determine the velocity. But for a fluid flowing through a closed duct, the Pitot tube measures only the stagnation pressure and so the static pressure must be measured separately.

- Measurement of static pressure in this case is made at the boundary of the wall (Fig. 1b). The axis of the tube measuring the static pressure must be perpendicular to the boundary and free from burrs, so that the boundary is smooth and hence the streamlines adjacent to it are not curved. This is done to sense the static pressure only without any part of the dynamic pressure.

- A Pitot tube is also inserted as shown (Fig. 1.b) to sense the stagnation pressure. The ends of the Pitot tube, measuring the stagnation pressure, and the piezometric tube, measuring the static pressure, may be connected to a suitable differential manometer for the determination of flow velocity and hence the flow rate.

2. PITOT STATIC TUBE

The principle is based on the Bernoulli Equation where each term can be interpreted as a form of pressure

$p + 1/2\ \rho v^2 + \gamma z$= constant along a streamline

- **Static Pressure**

The first term - *p* - is the static pressure. It is static relative to the moving fluid and can be measured through an flat opening in parallel to the flow.

- **Dynamic Pressure**

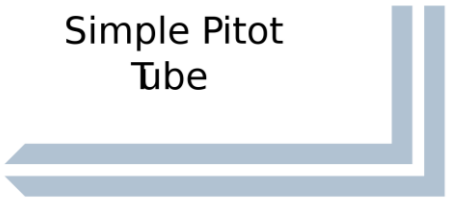
The second term - $1/2\ \rho v^2$ - is called the dynamic pressure (velocity head).

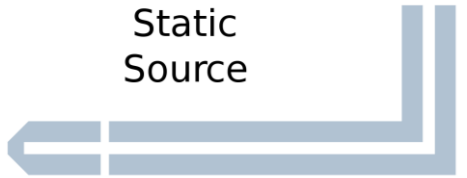
- **Hydrostatic Pressure**

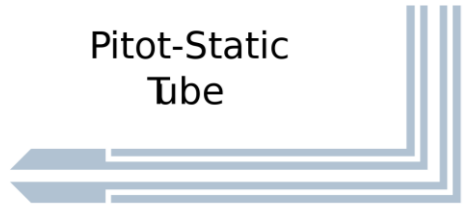
The third term - γz - is called the hydrostatic pressure. It represent the pressure due to change in elevation.

- **Stagnation or total pressure**

$$p_t = p_s + \left(\frac{\rho u^2}{2}\right)$$







2. PITOT STATIC TUBE

The tubes recording static pressure and the stagnation pressure (Fig. 1) are usually combined into one instrument known as Pitot static tube (Fig. 2).

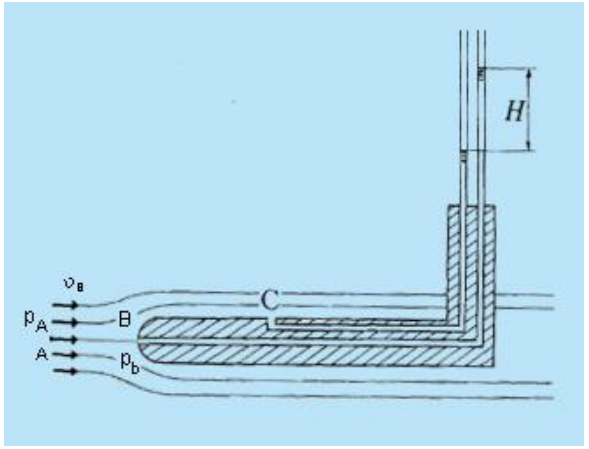


Fig. 2. Pitot Static Tube

The tube for sensing the static pressure is known as static tube which surrounds the pitot tube that measures the stagnation pressure.

Two or more holes are drilled radially through the outer wall of the static tube into annular space. The position of these static holes is important. Downstream of the nose N, the flow is accelerated somewhat with consequent reduction in static pressure. But in front of the supporting stem, there is a reduction in velocity and increase in pressure.

2. PITOT STATIC TUBE

The static holes should therefore be at the position where the two opposing effects are counterbalanced and the reading corresponds to the undisturbed static pressure. Finally the flow velocity is given by

$$V = C\sqrt{2\left(\frac{\Delta p}{\rho}\right)}$$

where Δp is the difference between stagnation and static pressures.

The factor C takes care of the non-idealities, due to friction, in converting the dynamic head into pressure head and depends, to a large extent, on the geometry of the pitot tube. The value of C is usually determined from calibration test of the pitot tube.

Note

- The original Pitot tube included basically a total head reading. L. Prandtl improved the device by introducing a pressure (or piezometric head) reading. The modified Pitot tube is sometimes called a Pitot-Prandtl tube.