LECTURE – 2

THE CONTENTS OF THIS LECTURE ARE AS FOLLOWS:

1.0 PITOT-STATIC TUBE

The Pitot-static tube is an instrument which uses the principle of pressure exerted by flowing air and is suitable for measurements of high velocity. Unlike an anemometer it is not capable of measuring average velocity directly but measures the velocity at a given point in the airway/duct. The instrument consists of two concentric tubes out of which the outer tube, which contains perforations in the form of small holes drilled at right angles to its periphery, measures the static head while the inner tube measures the total head (Fig. 1).

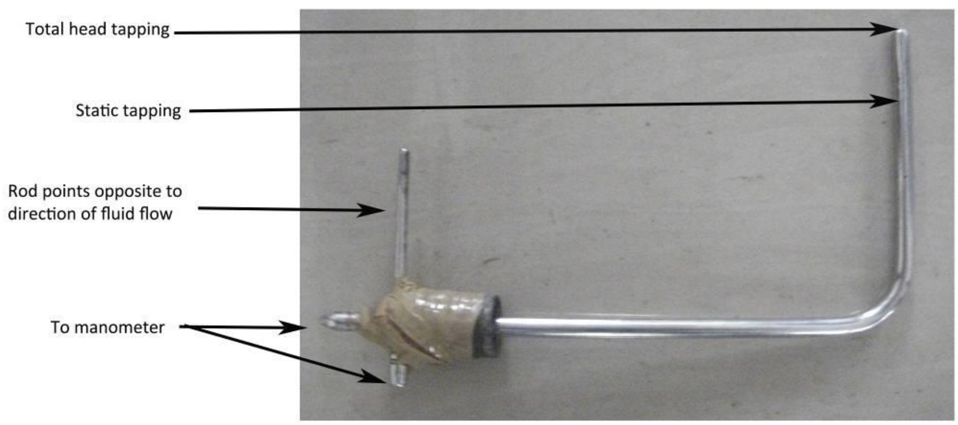

Fig. 1 Pitot-static tube

The total pressure tapping generally measures the total pressure with reasonable accuracy, the static pressure tapping needs to be suitably positioned on the outer tube to minimize the effect of interference created by the stem and the total pressure tapping. The nose is designed so as to give least resistance to flow.

(a) **(b)**

Fig. 2 showing the connections of the pitot-static tube with manometer using rubber tubes and its mounting on a duct

Fig. 2 shows the connections of the pitot-static tube with manometer using rubber tubes and its mounting on a duct. For velocity measurements, the two connections i.e., total and static pressure connections are attached to the two limbs of a manometer which will read the velocity pressure, which is related to the total and static pressures as

$$\mathbf{P_v} = \mathbf{P_t} - \mathbf{P_s} \quad \text{Pa}$$

Where $\mathbf{P_v}$ is velocity pressure in Pascal

$\mathbf{P_t}$ is total pressure in Pascal

$\mathbf{P_s}$ is static pressure in Pascal

The readings of velocity pressure, static pressure and total pressure are in mm which needs to be converted to Pa, using the relation $P = \rho g h$ (Pa); where ρ = density of the liquid used in the manometer (kg/m^3), g = acceleration due to gravity, 9.81 m/s^2 and h = difference of the two limb readings of the manometer (m)

Now, the actual air velocity, **v**, is related to the velocity pressure $\mathbf{P_v}$ as

$$v = \sqrt{\frac{2P_v}{\rho}}\ \mathrm{m/s}$$

Where

ρ = actual density of air (kg/m^3)

The accuracy of the readings obtained from the pitot-static tube depends on the angle of yaw. The angle of yaw is the angle between the direction of airflow and the horizontal axis of the head of the pitot-static tube. The maximum permissible angle of yaw for least error is around 10^0 (0.175 rad). During measurement, it is advised to keep the lowest angle of yaw by turning the head of the pitot-static tube in different directions by trial and error. At the lowest angle of yaw, the velocity pressure recorded will be highest. The pitot-static tube can measure velocities accurately over a large range and the minimum velocity that it can measure generally depends on the sensitivity or capacity of the manometer being used with it. The size of the pitot-static tube to be used for a given duct depends on the size of the duct itself. For ducts of diameters less than 200mm, it is preferable to use small sized pitot-static tubes rather than the normal sized ones which are generally used in mine roadways. This ensures that accuracy of the reading is not compromised.

Since the reading obtained by a Pitot-static tube gives only the point velocity it is necessary to adopt a technique to obtain the average velocity of the airway. To do this, the cross section of the airway/duct is divided into a number of equal areas similar in shape to the complete opening and the velocity at the centre of each area is measured by this instrument (Fig. 3). These readings are averaged over the whole area of the airway to give an estimate of the average air velocity throughout the cross section of the airway. As shown in Fig. 3, the velocity in each shaded section should be the average from several readings distributed over the section. This is to reduce the error in velocity measurement as we all know that the velocity gradient changes most rapidly near the walls.

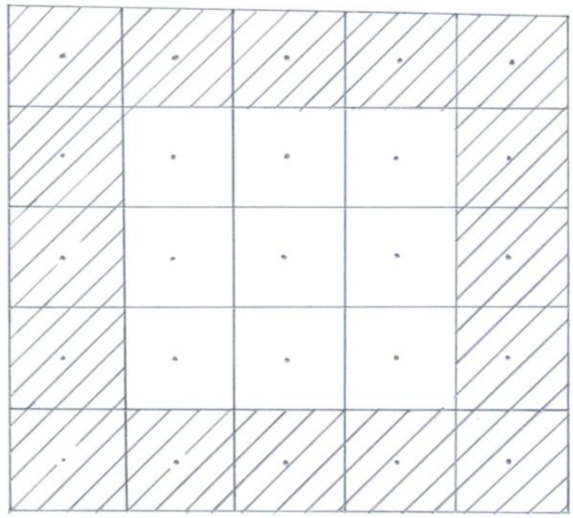

Fig. 3 Dividing the cross-section of the roadway into number of equal areas (after McPherson, 1993)

2.0 SMOKE TUBE

This method is generally useful only in airways that require air velocity measurements of very low magnitudes. The method essentially consists of releasing a white smoke-cloud from a 'smoke-cloud generator' into the air-stream. The time taken by this smoke to travel a pre determined distance is recorded using a stop-watch and velocity of this smoke is calculated by using basic kinematic equations i.e., velocity=distance/time. This velocity roughly gives the velocity of the air-stream in the duct if the smoke is let out at the center of the cross-section of the duct. Otherwise, it is necessary to add the required correction factor to the calculated velocity readings to get the average velocity of the flow. The correction factor is generally taken as 0.8 when recording is taken as near to the centre of the cross-section of the duct as possible. The disadvantage in this method is that sometimes it is difficult to identify the smoke clearly at the end point, to stop the stop-watch for time measurement, as it has considerably diffused in the mine air. For a good reading, it is advisable to choose an airway such that it takes around one minute for the smoke to reach downstream in it.

The construction features of the smoke-cloud generator/smoke tube are as follows:

- Small glass tube filled with granular pumice stone, soaked in titanium tetrachloride or anhydrous tin
- Glass wool
- Rubber aspirator bulb for procuring an air current through the tube when pressed, initiating the process of white smoke formation

3.0 KATA THERMOMETER

The use of this instrument and its utility in air velocity measurement is discussed under the Lectures in 'Heat and Humidity'.

4.0 HOT WIRE ANEMOMETER

These instruments are particularly useful in the airways with low velocity air streams. They are quite accurate till a velocity of 0.1m/s. The hot-wire anemometers work on the principle that the heat energy will be removed from a heated element present in a fluid in motion, at a rate dependant on the rate of mass flow over the element.

A wire element (usually platinum) is present in the hot wire anemometer, which forms a limb/arm of a Wheatstone's network. There are two variations of the hot wire anemometer, namely, the constant resistance and the constant current type (Fig. 4).

5.0 TRACER GAS METHOD

This technique uses the gases like oxides of nitrogen whose concentration can be detected fairly easily with a high degree of accuracy using infrared gas analyzers.

Oxides of nitrogen are suitable for mine air quantity surveys because

- Normal mine atmosphere has very low concentrations of this gas
- Extremely low concentrations of this gas for short periods of time is quite harmless for human beings

This method is useful for difficult situations like leakage flow through waste areas, main shafts and other regions of high velocity and excessively turbulent flow, or total flow through composite networks of airways (McPherson, 1993).

Hot wire anemometer

Constant resistance type

- This is the more popular design of hot wire anemometers
- Here the resistance, i.e., the temperature of the wire element is kept constant while electric current changes through it as the air velocity changes

Constant current type

- This design is a lesser used design
- In this case, the current is kept constant while the electric resistance or temperature of the element is observed.

Fig. 4 Types of Hot wire anemometers

The procedure of measurement of quantity of air using this method involves releasing a volume '**V**' of nitrogen dioxide at a given point in the mine airway and estimating its concentration at regular intervals of time at a fixed distance downstream where almost complete dispersion of the gas would have occurred. This measurement of concentration is done till the concentration reads almost zero. Based on the readings, a concentration-time curve is plotted and area under the curve (**I**) is estimated (Fig. 5). This area divided by total time gives the average concentration of the gas. Air quantity can then be determined by the formula

$$\mathbf{Q} = \mathbf{V/c}$$

Where

Q = Quantity of air flowing per unit time through the roadway (m^3/s)

q_g = Volume flow of tracer gas (m^3/s)

c = Average concentration of the gas in the time interval (fraction by volume)

V = Volume flow of nitrogen per second (m^3/s)

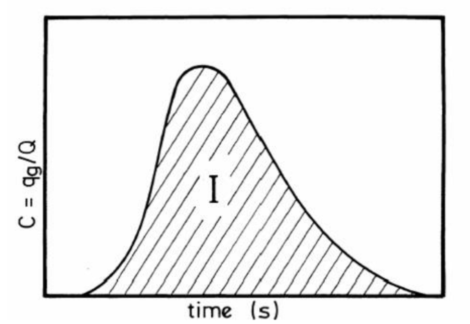

Fig. 5 Concentration-time curve at a tracer gas monitoring station (after McPherson, 1993)

REFERENCES

Banerjee S.P. (2003); "Mine Ventilation"; Lovely Prakashan, Dhanbad, India.

Deshmukh, D. J. (2008); "Elements of Mining Technology, Vol. – II"; Denett & Co., Nagpur, India.

Hartman, H. L.,_Mutmansky, J. M. & Wang, Y. J. (1982); "Mine Ventilation and Air Conditioning"; John Wiley & Sons, New York.

Le Roux, W. L. (1972); Mine Ventilation Notes for Beginners"; The Mine Ventilation Society of South Africa.

McPherson, M. J. (1993); Subsurface Ventilation and Environmental Engineering"; Chapman & Hall, London.

Misra G.B. (1986); "Mine Environment and Ventilation"; Oxford University Press, Calcutta, India.

Vutukuri, V. S. & Lama, R. D. (1986); "Environmental Engineering in Mines"; Cambridge University Press, Cambridge.