# LECTURE – 3

**THE CONTENTS OF THIS LECTURE ARE AS FOLLOWS:**

## 1.0 AIR QUANTITY MEASUREMENT USING ORIFICE PLATES AND VENTURIMETERS

Orifice plates and venturimeters are devices that are generally used for measurement of airflow in ducts. They have a distinct advantage over other methods as they can be permanently fixed in the ducts. Thus it is possible for dynamic and continuous measurement of airflow using these devices. Their utility is especially felt during testing of mine fans.

### 1.1 Orifice Plates

An orifice plate basically consists of a thin plate with a small orifice/hole in it. The hole is, in most cases concentric with the plate but some manufacturers also design eccentric plates and segmental plates. Eccentric plates have the hole near the edges of the plate while the segmental plates generally have a hole shaped as a semi-circle. This plate is inserted into a pipe/duct through which the airflow takes place such that the axis of the hole in the orifice plate is parallel to the axis of the pipe. A manometer is attached through two holes on either side of the orifice plate on the pipe to record the pressure drop. Using this, velocity and flow quantity are calculated as follows.

The pressure drop, $\Delta p$ is given as

$$\Delta p = p_1 - p_2 = \frac{1}{2}\rho V_2^2 - \frac{1}{2}\rho V_1^2$$

But by continuity, we know that

$A_1V_1=A_2V_2$

Where

$p_1$ and $p_2$ are the pressures recorded on either side of the orifice plate in Pa

$\rho$ is the density of the fluid in kg/m$^3$

$A_1$ and $A_2$ are the areas of the duct on either side of the orifice plate in m$^2$

$V_1$ and $V_2$ are the velocities on either side of the orifice plate in m/s

Hence the above equation for pressure drop can be re written as

$$\Delta p = \frac{1}{2}\rho Q^2 \frac{1}{{A_2}^2}\left[1-\left(\frac{A_2}{A_1}\right)^2\right]$$

Where

$Q$ is the flow rate of the fluid in the duct in $m^3/s$

The value of $Q$ can be calculated by rearranging the above equation appropriately.

### 1.2 Venturi Meters

The venturi meter works on the principle that a pressure loss is observed at the smaller cross sectional area when a fluid is made to flow through a pipe consisting of cross sections as shown in Fig. 1.

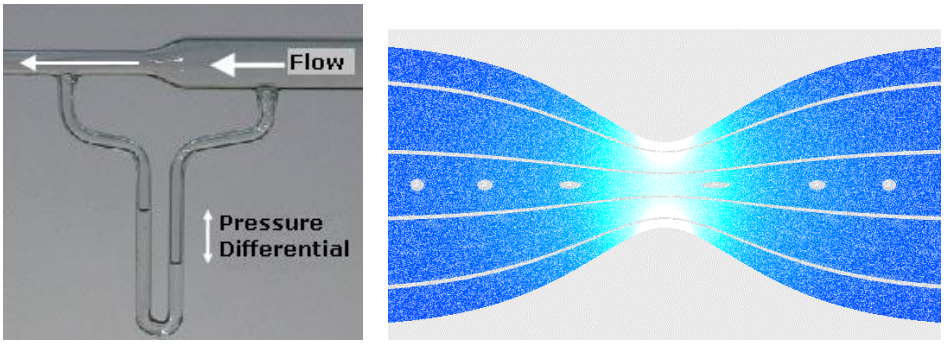


**Fig. 1 Venturimeter**

In this apparatus, the fluid whose flow rate is to be calculated is made to flow through a tapering or converging conical section and the pressure difference between the throat (where cross section is minimum) of the taper and the uniform cross section of the pipe gives an estimate of the flow rate. Because of a gradual taper the phenomenon of vena contracta (sudden contraction of the pipe cross section leading to a head loss at the region) doesn't occur.

This method has a slight advantage over the orifice plates due to the following

- This is suitable for any kind of fluid-clean, dirty, slurry, viscous etc.
- Accuracy is better
- Various pressure losses are low
- Cheaper compared to the installation of the orifice flanges

## 2.0 SELECTION OF MEASUREMENT STATIONS FOR PRESSURE QUANTITY SURVEY

Measurement stations are generally fixed permanently after extensive reconnaissance to ensure as much accuracy as possible. The following criteria should be kept in mind while selecting a measurement station:

- It should preferably be in a straight roadway
- The associated roadway should have a regular cross section throughout its length to help maintain accuracy in area calculations
- No obstructions should be present near the measurement station
- The station should not be situated near junctions or bends in the roadway

## 3.0 MEASUREMENT OF CROSS-SECTIONAL AREA

The accuracy of calculation of air quantity is equally influenced by the accuracy of measurement of air velocity and accuracy in measurement of the cross sectional area of the roadway. Thus it is of utmost importance to ensure that a systematic method is used to carry out area measurements.

Normally, one of the following methods is used for the cross-sectional area measurements:

- Taping
- Offset method
- Profilometer method
- Craven sunflower method
- Photographic method

### 3.1 Taping

This is the simplest and the most common method of cross sectional area calculation in mines. It also has the disadvantage of having the highest error among all methods. It is most suitable when the area in question is a simple figure like a rectangle, circle or triangle. Complex figures may be subdivided into the above mentioned simple figures and taping may be carried out by calculating the parameters required to arrive at the area (eg. For a rectangle, it may be required to tape the length and breadth to calculate the area).

### 3.2 Offset Method

In this method, strings are erected to develop a regular or simple figure within the cross section of the airway. These strings may be two vertical and two horizontal wires to emphasize a rectangle or an appropriate number for a polygon etc. To draw a profile of the cross section on a graph paper, taping is done from these wires to the periphery of the airway and at regular intervals around its perimeter.

### 3.3 Profilometer Method

This method uses a plane table or a drawing board with a paper pinned to it. The board is kept vertically attached to a tripod in the plane of the cross section of the required airway. Measurements are made from a point on the paper which is at the centre of the paper (and preferably, the centre of the cross section of the duct) to the wall of the duct. Appropriate scaling is done and the airway profile is

reconstructed on the paper with good accuracy. The tape measure can be replaced by an ultrasonic distance measurement device in case of electronic versions

### 3.4 Craven Sunflower Method

The method involves the use of a graduated brass rod which is rotated about the centre of the duct in a full circle. The measurements are made at various angles with the rod being adjusted to record the length of these angles from the centre to the periphery. These measurements are scaled down and area is calculated appropriately.

### 3.5 Photographic Method

This method consists of painting the periphery of the section of the airway whose cross-sectional area is required to be measured, by a white paint. Subsequently, it is required to place an appropriate scale such as the leveling staff is fixed vertically within the perimeter of the airway. A camera is placed such that its axis is parallel to the axis of the airway and its lens is equidistant from all points of the painted perimeter. A photo is taken and area is appropriately calculated after the photo is developed by overlapping a transparent graph sheet with the photo.

## 4.0 PRESSURE SURVEYS

Pressure surveys are required to be undertaken in mines to measure the pressure difference between any two points in a roadway/airway so that

- The presence and extent of air leakages can be estimated
- A booster fan can be installed in the particular airway, in case the airway is receiving lesser air supply than minimum requirements

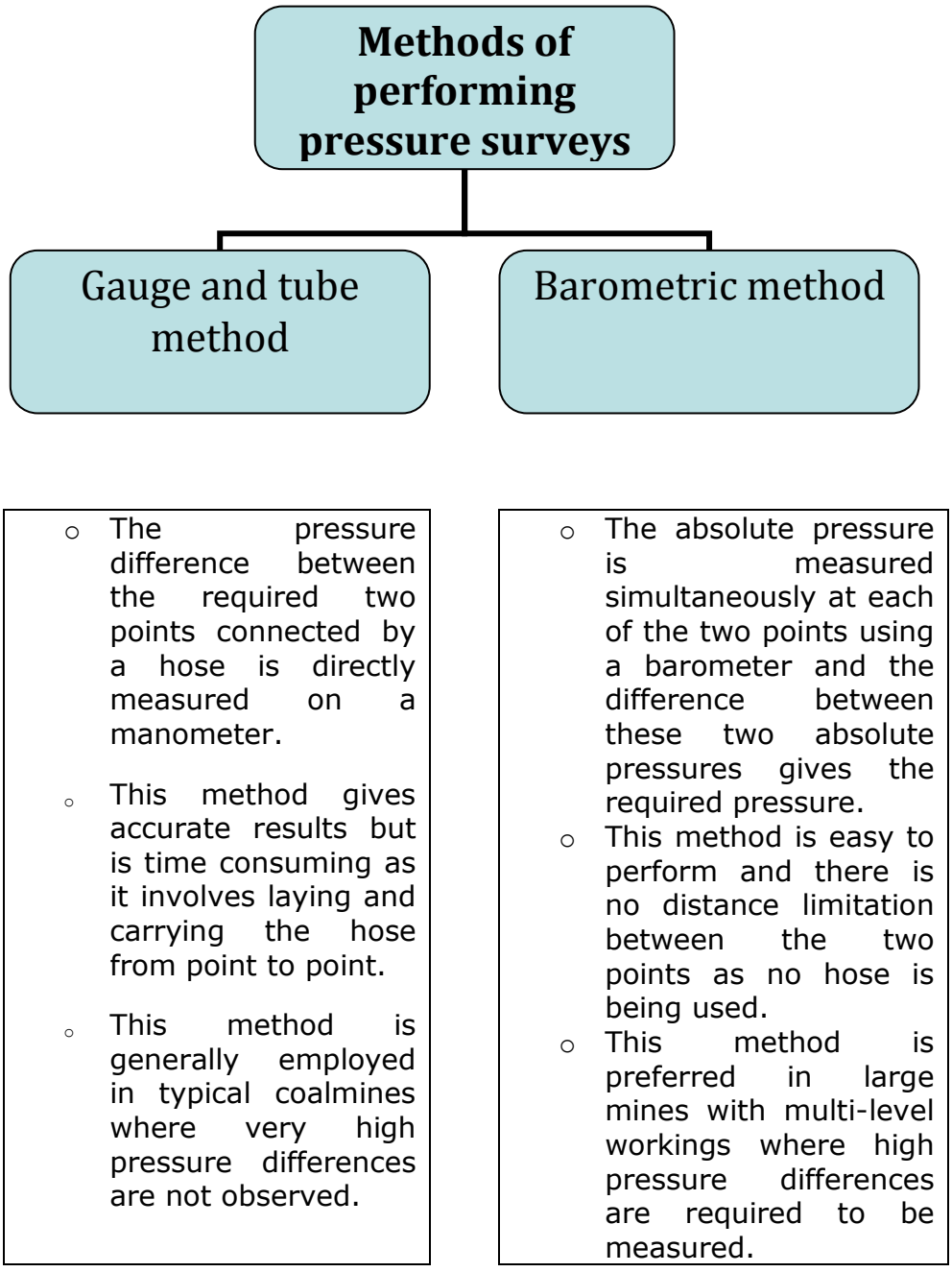


**Fig. 2 Flow chart showing methods of performing pressure survey**

- Airway resistance and friction factor can be estimated which will be required in case any alteration of the existing ventilation network is planned

A flowchart showing the methods of performing pressure survey is shown in Fig. 2

### 4.1 Aneroid Barometer

An aneroid barometer is a pressure recording instrument which consists of a nearly perfect vacuum filled capsule (Fig. 3). A spring is provided to prevent the collapse of the capsule. The pressure measurement involves the bending/flexing of certain parts of the spring/capsule when a pressure difference is felt. This flexing is exaggerated and transmitted to a calibrated needle which shows the true pressure of the surroundings. At all times the capsule is required to be a vacuum filled container for this device to show the correct readings. At the normal atmospheric pressure, the needle is calibrated to show either zero reading or the current pressure depending on the manufacturer's design.

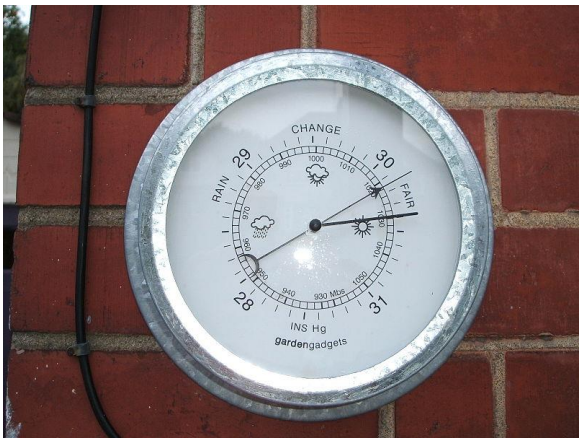


**Fig. 3 Aneroid barometer**

### 5.0 EQUIPMENTS REQUIRED FOR A PRESSURE-QUANTITY SURVEY

- An inclined manometer which can record pressures up to 3 kPa
- Flexible plastic tube/pipe of required length-for large distances
- Pitot tubes - two sets
- Tape – one
- For quantity measurements, an anemometer, stopwatch, and steel tape may be carried

- Aneroid barometer for measuring absolute barometric pressure at stations

## 6.0 ORGANIZATION OF PRESSURE-QUANTITY SURVEYS

A pressure-volume survey must be well planned and systematically approached. Generally it involves the presence of two teams, one of which will work on the airflow measurements and the other on the pressure survey. Both the teams must coordinate properly to ensure the success of the survey.

The following steps are carried out as part of the initial planning for the survey:

- At least a week before a major survey, all instruments are checked for faults and suitably calibrated/standardized.
- The mine plan is carefully studied and survey routes are selected. A full mine survey will involve surveying of the major ventilation networks of the mine. Routes are selected such that they form a closed loop. In case of large ventilation channels the loop is divided into smaller sub-loops for ease of survey.
- A preliminary reconnaissance survey is carried out to mark all the survey stations on the ventilation plan as well as on the walls of the roadway/airway.
- The traverse routes and survey station sites are finalized and a time-table is prepared for all the days required for the survey, clearly stating the work to be done on each day.

While performing the survey the following must be observed:

- The survey must be performed when the labour force in the mine is at a minimum. Thus the most appropriate time for surveying is during weekends and night shifts.

- Care should be taken that the frictional pressure loss and airflow rate are measured almost simultaneously or with as little time interval between them as possible. Hence the two teams must coordinate as closely as possible.
- Field books or observation books must be maintained such that any person with relevant qualification must be able to understand it.
- Calculations must be carried out with a great amount of accuracy and checks must be carried out wherever possible by someone other than the person who performed the initial calculations.
- The survey work done on each day must be clearly recorded and a log book must be maintained for the same.

## 7.0 AIR QUALITY SURVEYS

Unlike pressure-volume surveys, which deal with the quantity of air and pressure through the roadways, air quality surveys are undertaken to measure the concentration of various gases and suspended particulates present in the air and to calculate temperature and humidity of the mine air. Broadly, this survey gives an assessment of the quality of the mine air. These surveys are required to be undertaken from time to time to ensure that the air quality stays well within the regulations set by the competent authorities (DGMS in India) and to ensure that a safe working environment is provided for the workforce of the mine.

This survey procedure is employed for at least one of the below two reasons:

- To track and estimate the quantity of pollutant levels
- To identify those areas in the mine where emission of gases, dust, heat and humidity is maximum or undesirable.

Gas concentration measurements are often made as part of pressure-quantity surveys while the barometric observations and dry and wet bulb temperatures

recorded during a pressure survey may be used for computing the psychrometric conditions of the survey traverse path.

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