1.0 Ventilation

1.1 Calculate the quantity of air.

COMPOSITION OF MINE AIR

Dry atmospheric air has the composition as given in Table. Composition of wet air is of course different depending on the moisture content.

Component	% by volume	% by mass
Oxygens (O_2)	20.95	23.15
Carbon dioxide (CO_2)	0.03	0.046
Nitrogen (N_2)	78.09	75.52
Argon (Ar) and other rare inert gases like Krypton, non, xenon etc.	0.93	1.284
Total	100.00	100.00

Mine air on the other hand, invariably contains some impurities. Even in the least contaminated state, mine air contains more carbon dioxide than ordinary atmospheric air as there is no plant world underground to reconvert carbon dioxide to oxygen. Moisture content of mine air is also normally higher than of surface air.

1.3 Describe the different types of Barometer.

Fortin Barometer: This is the commonest type of mercury barometer. It consists of a glass tube encased in a brass tube which protects the glass and carries the graduated scale. The glass tube is inverted over a cistern containing mercury. The level of mercury in the cistern can be varied by an adjusting screw so that the level can always be set to the zero of the scale. This enables the scale on the brass tube to read the height of the mercury column directly.

Kew-pattern Barometer: This, on the other hand, has a fixed cistern where the level of mercury in the cistern can not be adjusted. So, when the level of mercury in the tube changes due to variation of barometric pressure there is a change in the level of mercury in the cistern also. The amount of this change depends on the relative diameter of the cistern. If A1 is the internal cross-sectional area of the tube and A2 that of the cistern (excluding the outer cross-sectional area of the tail of the tube), then a rise of 1 mm in the tube will cause a fall of A1/A2 mm in the cistern so that the total rise in the barometer reading will be (A1+A2)/A2 mm. Or, in other words, for a barometric rise of 1 mm, the level of mercury in the tube will rise by A2(A1+A2) mm. To avoid computation after reading, the scale in such a barometer is graduated in units of A2/(A1+A2) standard units so that it gives the barometric reading directly. The value of A2(A1+A2) is usually kept between 0.95 and 0.99.

Aneroid Barometers : Mercury barometers have an accuracy of ± 0.025 mm Hg or ±3.33 Pa, but are not very portable or sturdy in construction. Hence for mining purposes, aneroid barometers are commonly used. The aneroid consists of a concentrically corrugated, evacuated chamber normally kept from collapsing by a spring inside it. It, however, collapses or expands under increasing or decreasing atmospheric pressure, the distortion being transmitted through a sensitive spring and a series of levers and chains to a pointer about 200 times and can be easily read. The accuracy of aneroids is of the order of ± 6.66 Pa. In more sensitive instruments measuring smaller ranges of pressure, the accuracy has been improved to ± 3.33 Pa.

1.4 Describe kata thermometer.

KATA THERMOMETER: The kata thermometer developed by Hill et al., as early as 1916 is a glass thermometer with a 40mm long and 20mm diameter bulb filled with coloured alcohol connected to a 200mm long stem having two smaller bulbs or reservoirs at the top and the bottom ends. The stem has two bulbs. When taking a reading with the kata thermometer, the bulb is first heated by dipping iit in hot water so that the liquid rises to the top reservoir. The bulb is then taken out of water wiped with a dry cloth and is allowed to cool in the mine air. The time taken by the thermometer to cool from 311 K is usually written on the kata thermometer. This factor divided by the time taken for the cooling gives the rate of heat loss from the kata thermometer.

The dry kata reading gives an estimate of the heat loss from the surface of the bulb due to radiation and convection and hence is of little importance, particularly under hot and humid conditions where most of the heat loss from the human body is through evaporation. All the same Hill advocates a dry kata reading of not less than 250 W m^{-2} for good working conditions.

1.6 Calculate ventilation pressure by using piton static tube.

THE PITOT-STATIC TUBE: The pitot-static tube, often erroneously referred to as the pitot tube consists essentially of a pitot tube or a total-head tube placed concentrically inside a static tube. It comprises a head which faces the air-stream and a stem bent at right angles to it. The pitot tube is nothing but a tube with an open end facing the air-stream so that it measures the total head whereas a static tube is one with its nose (which faces the air-stream) closed and with a few holes on the side of the tube there are two concentric tubes, the outer of which has a few holes on the sides. The annular opening between the two tubes at the nose end is sealed so that the inner tube records the total pressure and the outer, the static pressure only. The nose is total pressure and the outer, the static pressure only. The nose is suitably shaped so as to avoid undue turbulence and hence offer the least resistance to flow. The two component tubes of the pitot-static tube are connected to the two limbs of a manometer which reads the velocity pressure. The velocity can be obtained from the velocity pressure by using the relation

$$P_v = \frac{K v^2 p}{2}$$

Where

v = velocity in m s^{-1}

P_v = Velocity pressure in Pa,

P = density of air in kg m^{-3}

K = correction factor for the particular pitot-static tube (for standard designs, K = 1)

For normal density of air of 1.2 kg m^{-3}, equation 8.11 reduces to

$v = 1.29 \sqrt{P_v}$

1.7 Explain effects of heat & humidity.

It has been said earlier that the human body produces a lot of waste heat by the process of metabolism which has to be dissipated into the surrounding mine air.

The major part of the heat produced by the body is dissipated from the surface of the skin by radiation, convection and evaporation of sweat, though a very small part is dissipated from the lung through exhaled air. The heat transfer from the inner parts of the body to the skin is through the blood circulatory system, although conduction accounts for a minor part.

When the temperature of the atmosphere is 298 K or less, the normal blood circulation of the body along with conduction is sufficient to transfer the heat from the inner parts of the body to the surface of the skin. The heat transfer from the skin to the ambient air at these temperatures is mainly by convection and radiation. But above 298 K, the heat transfer to the skin has to be faster. Here, the vaso-motor control comes into operation, dilating the size of blood vessels and thus ensuring larger blood circulation to the skin. As the temperature rises above 302 K, the sweat glands start functioning and now the heat transfer from the skin is mainly by the evaporation of sweat.

When the dry bulb temperature of the mine air exceeds the body temperature (310.05 K0 the body can give away heat to the surrounding atmosphere by the evaporation of sweat only.

1.8 NATURAL VENTELATION

Small and shallow mines are sometimes ventilated by natural means only though the ventilation in such cases is usually poor, fluctuates to a large extent and is even subject to reversal of direction. In cases of emergency such as fires underground, mechanical ventilation can be subjected to control while natural ventilation cannot be. It is for these reasons that all mines should preferably be mechanically ventilated. However, natural ventilation does play a role in all mechanically ventilated mines.

CAUSES OF NATURAL VENTILATION

1. Temperature: Natural ventilation can be visualized to be caused by the difference in densities of air in the upcast and downcast shafts. The heavier air sinks down and the lighter air moves up thus setting up an air current. The difference in air densities in the upcast and downcast shafts is mainly caused by the heating and rarefaction of air in the mine workings due to the addition of heat from rocks, men, machinery. Lights, spontaneous heating etc.
2. Moisture content of the air: Addition of moisture in the downcast shaft decreases the density of air as moisture is lighter than air, but this also causes evaporative cooling of the downcast air and consequent increase in its density so much so that, in effect, evaporation of moisture in the downcast shaft usually aids natural ventilation.
3. Barometer Pressure: It is well known that air density is a function of barometric pressure. If the mean barometric pressure of the downcast air column is higher than that of the upcast air column, it helps natural ventilation and vice versa. However, since barometric pressure rarely varies to any appreciable extent from place to place within the limits of a mining property, the effect of such variation on natural ventilation is negligible.
4. Addition of Gases: Methane emitted from the workings of coal mines reduces the density of return air thus aiding natural ventilation. This effect may, however, be slightly offset by the cooling of mine air produced by the desorption of methane. Large addition of carbon dioxide on the other hand has the opposite effect.
5. Leakage: In multilevel mines, leakage of denser downcast air to the upcast shaft causes an increase in the density of upcast air, thus reucing natural ventilation. In view of the low efficiency of natural ventilation, of the order of 1.4 to 1.6 % it is important to minimize leakage of air from the downcast to the upcast shaft in order to get the maximum benefit of natural ventilation.
6. Circulation of refrigerated air: Circulation of refrigerated air through the downcast shafts increases the density of downcast air thus aiding natural ventilation to a large extent.
7. Other factors: Other factors such as spraying of water in the downcast shaft for preserving shaft timber from dry rot or minimizing fire hazard etc. or having steam pipes through the upcast shaft where steam is used underground help natural

ventilation by increasing the downcast air density or decreasing the upcast air density.

AMOUNT OF NATURAL VENTILATION

The quantity of air circulated by natural ventilation depends on the above factors, the most important of them being the heat added to the air from the strata in the working. In shallow mines the natural ventilating pressure may be of the order of a few pascals, but in deep and hot mines, it increases considerably varying from 250 Pa to even 750 Pa. In some hot and deep mines such as Robinson Deep on the Rand, South Africa, where refrigerated air is sent down the intake shaft, the N.V.P. is estimated to be of the order of 1200 Pa.

2.0 AIR CROSSING AND DISTRIBUTION

2.1 Describe ventilation stopping, air crossing, ventilation door.

STOPPING: Stopping may be temporary or permanent. Temporary stopping, though commonly used in coal mines (particularly with bord-and-pillar method of working), are rare in metal mines where most stopping or bulkheads are of a permanent nature.

Temporary stopping's in coal mines are usually made of brattice cloth, tarred paper or plastic cloth with wire netting reinforcements. They can be hung as curtains for allowing access through the roadway or nailed to a framework, the former allowing more leakage. Even the latter can allow substantial leakage at the periphery of the airway. Inflatable plastic stopping have been designed to minimize such leakage. These materials are, howeer, rarely used in metal mines where the stronger blasting concussion might damage them easily. Besides, they make a poor fit against the rough walls of the drives in metal mines and hence cause a lot of leakage. Temporary bulkheads in metal mines are usually made of wooden boards nailed on to a skeleton frame of wood, the gaps between different boards as well as those between the boards and the rock wall being closed air tight by stuffing them with rags and plastering with clay.

Permanent stopping in coal mines are usually made of brick or cement-concert walls. A good foundation reaching up to solid unfractured ground surrounding an airway is essential for preventing leakage, particularly in case of stopping erected to seal off fire areas. According to Indian coal mines regulation, all stopping between main intakes and returns should be either of brick work or masonry of a minimum thickness of 250mm and suitably plastered by lime or cement mortar. They should be accessible for inspection.

AIR CROSSING: Air crossing become necessary when return air has to be taken across intake. In metal mines, the system of ventilation is usually such that air crossings are rarely required, but in coal mines where main return and intake airways run close together, their use becomes essential. Air crossing must be thoroughly leak proof since they generally involve main returns and intakes. They are usually made of brick or concrete walls covered with a reinforced concrete roof. Wooden roofs, though sometimes used, are very leaky, and are inflammable. According to Indian regulations, air crossing should be fireproof and in gassy coal mines, explosion proof too. They should be of a minimum thickness of 250mm if constructed of brick or lightly reinforced concrete or of 150mm if constructed of properly reinforced concrete. Sometimes brick or concrete arches may be used instead of the rectangular construction.

Natural air crossing, where there are a few meters of rock separating the intake from the return, are the best from the point of view of leakage and are definitely explosion proof though they are costlier. Air crossings can be overcast or undercast, the former being more common. Undercast air crossing can be made by digging up the floor, but are less common because of their quantities of return air can be taken across the intake through one or more large diameter pipes or ducts.

VENTILATION DOOR: Where access through stopping's is essential, doors are used. The term door usually means the assembly of both door and frame. The frames are set in suitable air

-tight stopping's, made usually of cement concrete and the doors hung from them vertically by means of two to three strap iron hinges. Indian coal mines regulations require that the thickness of the masonry or concrete wall in which the door frame is set should not be less than 250mm. single doors are most common in use though double doors are sometimes installed where a wide opening is required. Most double doors close in one plane though double V-doors operated manually or by compressed air or electricity are sometimes used on rope-haulage roads. In some cases automatic sliding doors have been used on rope haulage roads. The size of doors is often as large as that of the stopping itself except in airways which are infrequently used for the passage of men only ; in such cases small doors of 0.6 X 0.9m size may serve the purpose. Doors range in size from about 1.5 X 2m in metal mines up to 2 X 4m in coal mines, depending on the width of cars that have to pass through the door.

Doors should preferably open on one side, i.e. the high-pressure side, opening in the other direction being checked by the frame. They should be so installed that they close automatically if left open. In coal mines, this is commonly achieved by installing the frame at a small angle of about 0.175 rad (10°) with the vertical so that the door closes by its own weight. In metal mines, counter-weights or springs along with manually operated catches are usually relied upon for keeping the doors, they are often blocked open by irresponsible trammers so much so that in gassy coal mines it becomes necessary to place special operators at the doors. In coal mines, regulations provide that when a door is frequently used for the passage of men or material, an attendant shall always be placed at the door.

2.1 Define splitting of air current.

SPLITTING: When a mine has several working districts, it is preferable to divide or split the air required for the mine to the repective quantities needed in these districts and supply them through separate ventilation routes or circuits in parallel. Just as combination of airways in parallel reduces their resistance, splits reduce the overall resistance of the mine and increase the fan quantity. Control of quantities delivered to different districts to suit their needs can be done easily by controlling the resistance of the splits. Besides, splitting helps in providing fresh uncontaminated air to each district. Explosions or fires occurring in one district can be easily confined to that district by suitable ventilation control measures. Splitting helps in keeping down air velocities in roadways by distributing the quantity through several opening instead of one.

However, splitting has its disadvantages such as (a) the necessity of maintaining a larer number of airways and (b) adition of a greater amount of heat to the air by virtue of its low velocity and contact with a larger rock surface in the splits.

For ideal air distribution, (a) the splits should have resistances commensurate with their air requirements ; (b) they should be fairly long so that the trunk airways connecting them to the shafts at both ends are as short as possible, as these trunk airways are usually overloaded and can cause large friction losses ; and (c) the number of splits cause a large number of faces to be ventilated by a single split whereas too many splits may produce sluggish ventilation at the face.

3.0 MECHANICAL VENTILATION

3.1 Explain construction & principle of operation of centrifugal flow fans.

A centrifugal fan essentially consists of an impeller, rotor or wheel rotating inside a volute casing. The impeller, in turn, consists of several blades or vanes mounted on a central hub over the driving shaft. When the impeller rotates, air is drawn into it at the hub and is discharged at the periphery into the casing. Following figure indicates an impeller of a centrifugal fan in which

U= the peripheral velocity of the impeller in m s^{-1}

V= the absolute velocity of flow in m s^{-1}

W= the relative velocity of flow in m s^{-1}, i.e. velocity of air relative to that of the impeller so that V is the resultant of W and U

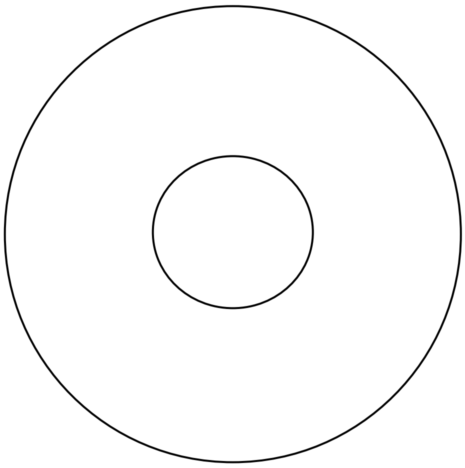
V_R= radial component of the absolute velocity of flow

V_U= tangential component of the absolute velocity of flow

r_1= radius of the impeller inlet in m.

r_2= radius of the impeller outlet in m.

and subscripts 1 and 2 indicate the flow conditions at the entrance and dischare of the impeller respectively.



Velocity triangles at the inlet and outlet of a centrifugal impeller.

Now consider a quantity of air Q passing through the impeller per unit time. The mass of this air is equal to $Q\rho$ kg s^{-1} where Q= quantity in $m^3 s^{-1}$ and ρ= density of air in kg m^{-3}. This mass of air rotates in the impeller about the axis C. the torque T causing this motion is given by the rate of change of angular momentum or moment of momentum of air at the impeller inlet is equal to $Q\rho V_{u1} r_1$ since it is only the tangential component $Q\rho V_{u1}$ of the linear momentum $Q\rho V_1$ which is effective, the radial component $Q\rho V_{R1}$ having no moment about C. Similarly the moment of momentum of air the impeller oulet is equal to $Q\rho V_{u2} r_2$ or the change of the moment of momentum from the impeller inlet to the impeller outlet, which is also the rate of change of moment of momentum since the change takes place in unit time, is equal to

$QP(V_{U2} r_2 - V_{U1} r_1)$ or $T= QP(V_{U2} r_2 - V_{U1} r_1)$ J

3.2 State fan laws & calculate fan efficiency.

Hydraulic efficiency is then defined as the ratio of the available total head to the input head.

The ratio of the input head to Euler's head is usually referred to as vane efficiency, although there is no actual loss involved.

Sometimes the ratio of the actual total head to the theoretical or Euler's head is termed as manometric efficiency, but this has no physical meaning and hence serves no useful purpose.

Leakage through clearances between the rotating and stationary parts of a turbo-machine causes capacity losses. If Q=actual developed capacity of the fan and QL= leakage capacity loss then the volumetric efficiency is given by the relation

Mechanical efficiency is tus the ratio of the power actually absorbed by the impeller and converted into head to the power applied to the shaft.

The gross or total efficiency is the ratio of the power in the air to the input power (it is often called mechanical efficiency though obviously the term is not quite appropriate).

Total efficiency is usually calculated on the basis of total head but when calculated on the basis of static head, it is called static efficiency. It is the total efficiency which is however used in design procedure.

3.3 Explain installation of mine fan with reversal arrangement.

In Indian mines it is required by law to provide arrangements for the reversal of air-current in order to meet with eventualities of fires in the downcast shaft or near the downcast shaft-bottom. Air reversal may well serve the purpose in coal mines where the number of openings are usually limited, but it is of not much use in metal mines where there are many shafts and outlets and there is usually a strong natural ventilation. In such cases, a more elaborate ventilation control by doors and readily erected stoppings becomes more important than reversal of air-current for controlling underground fires. However, in metal mines with a limited number of openings it is wise to provide for reversal of air-current particularly since it is the intakes which are usually dry and liable to fire hazards. In mines where there is a strong natural ventilation aiding the fan ventilation, it should be ensured that the fan generates enough pressure to overcome the opposing natural ventilating pressure in the event of a reversal of air-flow. It must be noted here that the decision for the reversal of ventilation is a very important one which can be taken only by responsible officials and hence reversing arrangements should be kept locked and operated by responsible persons only.

3.5 Explain fan characteristic and mine characteristic.

The most important characteristic of a fan is the head-capacity characteristic which determines its applicability to a particular mine characteristic, the other characteristics such as of efficienc-capacity and input power-capacity being of secondary importance.

Actual characteristics are therefore drawn from test data on fans and hold good for other geometrically similar fans. The pressure, power and efficiency characteristics of fans total head or pressure.

The fan velocity-pressure characteristic can easily be drawn from a knowledge of the cross-sectional area of the fan outlet.

The head characteristic of forward-bladed fans falls at first with increasing capacity until it flattens out or even shows a rising trend before starting to fall again.

The power curves of both forward and radial-bladed fans are rising, but this is not really a serious disadvantage if the operating point does not vary, or in other words, if the system characteristic does not change. The power characteristic of the backward-bladed fan is non-overloading in nature thus making the fan more suitable for operation over a wide range of quantity without the motor getting overloaded. The efficiency characteristics of all centrifugal fans are usually with a flat peak which means that good efficiency is maintained over a wide range of operation.

3.6 Describe methods for output control fans.

Control of the capacity of a centrifugal fan can be achieved in three main ways.

(a) Constant speed of drive and fan with capacity control by devices which modify the fan or the system characteristics : Such devices include (i) damper control and (ii) inlet-vane or inlet-louvre control. These devices are, however, not commonly used in mine fans.

(b) Constant-speed drive with provision for variation of fan speed by auxiliary intermediate devices between the fan and the drive : Such devices include (i) hydraulic coupling (ii) electromagnetic coupling and (iii) V-belt of gear drive.

(c) Variable-speed drive directly coupled to the fan : such drives can be (i) D.C. motors , (ii) slip-ring induction motors, (iii) multispeed A.C. motors (iv) A.C. commulator motors or (v) steam turbines.

Any of the above methods can be used for the control of capacity of axial-flow fans. In addition, capacity of axial-flow fans can be varied by alteing thepitch of the rotor blades where the fan is provided with variable-pitch blades. Sometimes adjustable inlet guide vanes are used for imparting a swirl or counter swirl to the inlet air-flow for the purpose of varying output. These are less costly than adjustable otor blades but their range of efficient performance is not so wide.

4.0 BOOSTER FAN AND ITS EFFECTS.

4.1 Describe installation and location of booster fan.

As the name suggests, booster fans are those installed underground for boosting up or supplementing the air circulated by the main mine fan. They may assist the surface fan for ventilating the whole mine when they act in series with the surface fan, but such installations are rare since it is always better from the point of view of capital cost and efficiency to choose a single fan.

Booster fans usually circulate 25 to 50m^3s^{-1} at pressures varying from 0.25 to 1 kPa, though boosters circulating as much as 140 m^3s^{-1} at 1.5 kPa have been installed.

Booster fans are normally installed in the return airway so that they do not interfere with haulage. Belt drives are common with the driver (a flame-proof motor for gassy coal mines) being placed an adjacent room connected to the intake. The motor room is ventilated by intake air leaking through the recess in the partition between the fan and the motor room provided for the passage of driving belts. A bypass with a suitable air lock is provided alongside the airway housing the fan in order to provide access across the fan. Sometimes, if the main airway is required for occasional transport, the booster may be installed in a bypass airway while a suitable air-lock is provided in the main airway.

It is well known that the installation of a booster fan in one district reduces the flow of air in other districts and may even completely stop the air-flow through them if the booster is not judiciously selected and installed. That is why it is necessary and is also required by law that a careful ventilation survey be made and the ventilation needs of the different splits in the mine carefully assessed before deciding on the installation of the booster fan. Installation of a booster underground increases the total quantity circulating in the mine which shifts the operating point on the main fan characteristic.

Booster fans are liable to damage by underground explosions. To guard against such contingencies as well as the stoppage of the booster fan due to any other reason, it is necessary to ensure that in the event of the failure of the booster fan, a sufficient quantity of air is circulated to the split by the main mine fan in order to prevent the development of a dangerous atmosphere there. It is also for this reason that good maintenance by a separate underground crew is vital for ensuring continuous running of boosters even though it involves an increase in the maintenance cost of ventilation.

6.0 VENTILATION SURVEY

6.1 Describe methods of pressure survey using barometer, gauge and pitot tube with manometer.

Pressure survey with Differential Barometers: A very suitable instrument for underground measurement of pressure differences is the differential barometer which has been successfully used in mines in the U.S.S.R. This is free from the errors due to creep and set commonly met with in aneroid barometers although its sensitivity compares well with that of aneroid. It does not require much skilled operation and can take 15 to 20 readings in a shift.

The differential barometer consists of a vessel connected to the atmosphere by a tube having a tap. Tube one end of which extends nearly to the bottom of the vessel is connected at the other end to a U-tube manometer. Tube is connected to an aspirator bulb through the tap. The vessel is encased in an insulting vacuum flask filled with ice and contains 50 cm^3 of alcohol.

At the base station, two taps are opened and the aspirator is squeezed until the alcohol rises in the tube and fills it as well as the manometer. First tap is then closed. The liquid level in the exposed limb of the manometer is the same as in the vessel. The ice is then charged into the vacuum flask and 15 to 20 minutes allowed for the air in to attain the temperature of ice. Second tap is now closed so that the air in the vessel is maintained at 273.15 K temperature and at the atmospheric pressure of the base station. The instrument is now moved to the next station of measurement. If there is a change of atmospheric pressure, there will be a change in the liquid level in the exposed limb of the manometer. This difference in level can be measured by a suitable scale placed alongside the U tube. The level difference gives the difference in absolute pressure between the two stations since the change in liquid level is negligible. If the scale be graduated in millimeters and if alcohol be assumed to have a specific gravity of 0.8, a sensitivity of 7.8 Pa can be obtained. To have an accuracy of $\pm$5% in the measurement, the minimum pressure difference to be measured should be 156 Pa.

Differential Pressure Survey by Gauge and Tube: The differential pressure between two points is measured by a suitable water gauge or manometer, the two limbs of which are connected by flexible tubes to the two points of observation. For measurement of static-pressure differences, the two ends of the tubes are usually held in manholes on the sides of the airway, where there is no air velocity. If there are no suitable manholes available, static tubes can be used. The static tube is so oriented that the nose exactly faces the air-current when the true static pressure is recorded. Pressure surveys with gauge and tube are more accurate than with aneroid or differential barometers and are to be adopted where more accurate pressure surveys covering less extensive areas are required.

For accuracy however, sufficiently thick-walled rubber hoses or polythene tubes at least 12mm in internal diameter are used so as to avoid kinks and collapse of walls. They also withstand rough use in mines and ensure a long leak proof life. They are also able to withstand their own weight when suspended in shafts without undergoing distortion.

Joints should be as far apart as possible and should be mechanically string and leak proof. Leakage can be checked by closing one end of the tube and blowing air into it while it is placed under water. Choking of the tubes by kinking or by dirt and water should be avoided. The tube should be laid out in the airway sufficiently ahead of connecting to the gauge so that the air inside attains the ambient temperature. The inclined manometer commonly used for the survey should be calibrated prior to the survey. Where the inclination of the gauge is variable, it should be properly set to the desired inclination. The instrument should be properly leveled. When a U-tube gauge is used better accuracy is obtained if the average of two readings is taken by interchanging the connection of the tubes to the two limbs of the manometer. As in the case of aneroid surveying, here also it is necessary to ensure constancy of fan speed during the survey. A check on the natural ventilating pressure is to be kept during the survey and corrections applied in case of appreciable variations in N.V.P. The pit should be idle during the survey in order to avoid changes in the system characteristics.

6.2 Describe the method of measurement of cross-sectional area.

This is usually done by tapes. The work is simple if the airway cross-section is of a regular shape which can be divided into geometrical figures whose dimensions can be measured with a tape, but most commonly the shape of mine airways is irregular, where simple measurements by a tape will not do. In such cases any of the following methods can be used.

Tape Triangulation: In this method, a tape is stretched across the airway and with the help of another tape perpendicular offsets to the periphery of the airway on either side of the stretched tape are taken at regular intervals of 0.3-0.5 m. The measurements can be plotted to a certain scale and the area of the resulting diagram determined by a planimeter, or the area can be calculated using Simpson's rule for area as given below

Area = L / 3 (Sum of first and last ordinates + 4 times the sum of even ordinates + 2 times the sum of odd ordinates)

Where L=distance between ordinates.

A modification of this method is to have a wooden frame of a size a little smaller than the cross-section of the airway but more or less resembling it in shape. Offsets are taken from the periphery of this frame to the sides of the airway.

Plane Table Method: This utilizes a drawing board with a sheet of paper pinned on to it and mounted in the plane of the section of the airway to be measured. Measurements are taken from a central point on the paper to various points on the periphery of the airway by means of a tape and the lengths are plotted on the paper to a suitable acale in the directions of measurement. The area of the resulting diagram can be estimated by a planimeter or by calculation (areas of individual triangles formed by adjacent rays can be calculated and added together to get the area of the cross-section).

The Profilometer: this consists essentially of the equipment used in the plane table method except for the incorporation of a mechanical scaling device similar to that in a pantograph so that the profile of the airway is automatically plotted on the paper mounted on the plane table. This makes the measurement quicker and obviates any personal error in the plotting of the rays.

Craven Sunflower Method: This utilizes a graduated brass rod which is adjustable in length and can be rotated about a central point in the airway through a full circle. Measurements from a central point in the airway to the periphery are taken at various angles, the rod being adjusted every time so as to read the lengths at these angles. The measurements can be plotted to scale and the area computed there form.

Photographic Method: the photographic method consists of marking the periphery of the section of the airway with white paint and photographing it with a scale placed in the plane of the section by means of a suitable photographic camera. Alternatively, the periphery can be marked out by moving along it a beam of light from a cap lamp while the camera shutter is kept open. In this method, computation of area can be done only after the photograph has been developed and printed. Computation of area can be done either from positive prints or from the image of the negative by screening it through a suitable projector. A wide angle lens obviates errors in rough airways.

6.3 Describe the method of velocity measurements by using anemometer, voltmeter, and pito-static tube and smoke & cloud method.

Methods of velocity Mesurement : The velocity of flow varies from point over the cross section of a mine airway and the variation is irregular in nature, particularly if the airway has rough sides is not straight. The following methods can be adopted for computing the average velocity in such airways.

(a) Single point Mesurement : In this method, the measuring instrument (anemometer, velometer or pitot-static tube) is held at a fixed point on the cross-section of the airway and the reading multiplied by a method factor to get the average velocity. The instrument has to be held well away from the body of the observer. That is why anemometers should preferably be mounted on shafts. Usually readings at the centre are taken and these are multiplied by a method factor of 0.8 for getting the average values of velocity.

(b) Continuous Traversing : This is an approximate but quick method adopted with anemometers in minor airway which are neither very straight nor uniform in cross-section. This method gives an average accuracy of within 5% when used with a suitable method factor. The anemometer is held by hand or on a shaft away from the body and is traversed continuously either up and down or form side to side. The distance between adjacent legs of traverses should be about 300 mm for reasonable accuracy in normal-size airways and this distance should be uniformly maintained. The duration of traversing varies with the area of cross-section. One minute is sufficient for an area of about 3 m^3 whereas 3 minutes may be necessary for an area of 9 m^2.

(c) Precise Traversing : This is a very highly accurate method of measuring air velocity by anemometers, velometers or pitot-static tubes. An accuracy of 2% can be obtained with this method of traversing by anemometers. However, this method is more time consuming and hence should be confined to measurements in major airways only where a great deal of accuracy is needed. Precise traversing should be done in straight portions of airways of uniform cross-section and preferably in smooth lined portions away from any obstructions. The observer should stand at least 1.2m away from the instrument on the downstream side and the instrument should be mounted on a shaft. It is better if the observer stands in a suitable recess on the downstream side of the airway.

The Pitot-static Tube: The pitot-static tube, often erroneously referred to as the pitot tube consists essentially of a pitot tube or a total-head tube placed concentrically inside a static tube. It comprises a head which faces the air-stream and a stem bent at right angles to it. The pitot tube is nothing but a tube with an open end facing the air-stream so that it measures the total head whereas a static tube is one with its nose (which faces the air stream) closed and with a few holes on the side of the tube for recording the static pressure only. In the pitot-static tube there are two concentric tubes, the outer of which has a few holes on the sides. The annular opening between the two tubes at the nose end is sealed so that the inner tube records the total pressure and the outer, the static pressure only. The nose is suitably shaped so as to avoid undue turbulence and hence offer the least resistance to flow. The two component tubes of the pitot-static tube are connected to the two limbs of a manometer which reads the velocity pressure. The pitot-static tube may or not measure the true velocity pressure accordingly as it is designed. This deviation of a pitot static tube reading from the true value is due to the effect of flow around the nose and the stem which affects the static pressure reading.Pitot-static tubes are generally used for the measurement of air velocity in ducts. As the accuracy of the instrument is practically unimpaired for a large range of velocities, the minimum velocity that can be measured by a pitot-static tube is limited only by the sensitivity of the manometer that can be used under mining conditions.

Smoke-cloud Method: It consists essentially of a glass tube 125 to 150mm long and 12.5mm in diameter filled with granular pumice stone of 0.8-1.2mm size soaked with tin or titanium tetrachloride. The latter is often preferred as it is less corrosive. The two ends of the tube are plugged by glass wool and are sealed. When the tube is to be used, the sealed ends are broken off and the tube is attached to a rubber-bulb aspirator which, when squeezed, forces a current of air through the tube producing an atomized spray of the tetrachloride which coming in contact with the moisture of mine air, develops a thick cloud of white smoke. The tube normally has a charge to last for eight hours.

Under ordinary conditions, the tube is held in the airway and the smoke released across its axis at a suitable point in the cross-section. The taken by the smoke cloud to reach a distance of 8-10m is recorded by a stop-watch and the velocity computed thereform. However, this velocity may not represent the average velocity in the airway. The relation between the observed velocity and the average velocity depends on the position in the cross-section of the airway where the smoke cloud was released. The smoke cloud should not be released very near the sides lest it should be affected be eddy currents created by the rough surface of the airway. If it is released about quarter way from the side, it is found that the velocity obtained exceeds the average by 10% and this correction has to be applied to the observed velocity in order to get the average value.

Also, with very low velocities in airways of average cross section, the smoke cloud may thin out considerably so as not to be discernable at the normal distance of observation of 8-10m. In such cases a smaller distance of 4-5m may be used whereas with velocities ranging from 0.55-0.75 ms^{-1} and good lighting in the airways, the distance of observation can be increased to 15-20m.

A straight portion of the airway with uniform cross-section should be chosen for velocity measurement by this method and the average cross-section area of the test section should be obtained.