LECTURE – 1

THE CONTENTS OF THIS LECTURE ARE AS FOLLOWS:

1.0 HOW AIR FLOWS IN MINES

Whenever the word “ventilation” comes to our mind, we immediately get a picture wherein a person with a cardiac problem is put on a ventilator, which involves supplying of oxygen to him through hoses and gas cylinders. In no way, the VENTILATION in mines is different from it. Compared to the circulatory system in human beings, the ventilation in mines is no less complex. Analogous to the circulatory system, the intakes (intake roadways) are the arteries and the returns (return roadways) are the veins. The upcast and downcast shafts can be considered as pulmonary artery and the pulmonary veins respectively (Fig. 1 and Fig. 2). The bottom of the downcast shaft can be taken as the left chamber and that of upcast shaft as right chamber of the heart. The atmosphere at the surface can be considered as that of the lungs. The various machinery, persons and workings in the mine can be considered as different parts of the body.

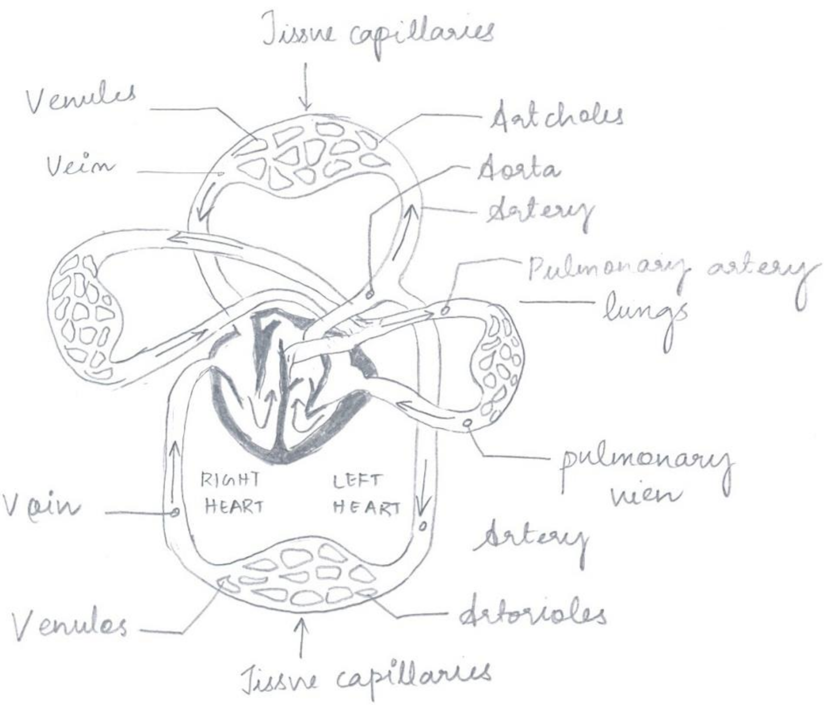

Fig. 1 Human circulatory system

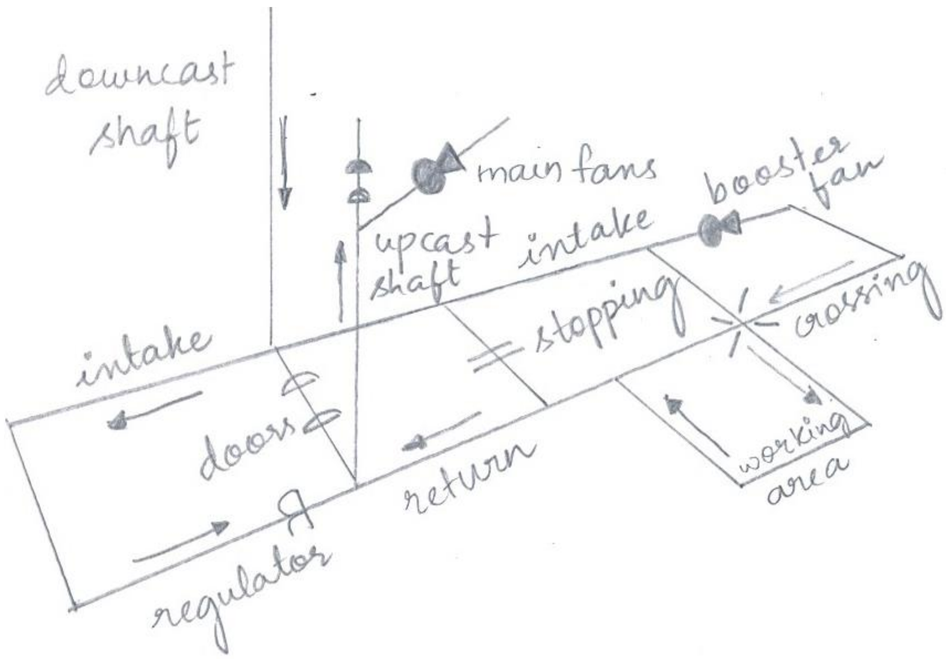

Fig. 2 Typical layout of a mine ventilation system with different ventilation structures (after McPherson, 1993)

While planning for ventilation network we have to consider the shape and size i.e. geometry and extent of mine openings. Ventilation planning also needs to consider other factors which includes considering the amount of heat that will be added up in the course of air flow, the minimum quantity of air supply to every person, the considerable loss due to leakage, the velocity of air to be maintained within permissible limits, and the psychometric conditions in the underground workings. The complexity further increases as we need to plan for ventilation according to the method of mining as well as local regulations. Let's have a look at different types of mining methods and their corresponding ventilation layout.

Fig.3 and Fig. 4 shows the layout of ventilation in advancing longwall and retreating longwall method of mining respectively. These layouts show that air through main gate or intake enters the mine, travels through all the faces and then comes back to the surface atmosphere via return or tail gate. We shall also discuss regarding stoppings, doors etc. when we come across essential elements of mine ventilation system.

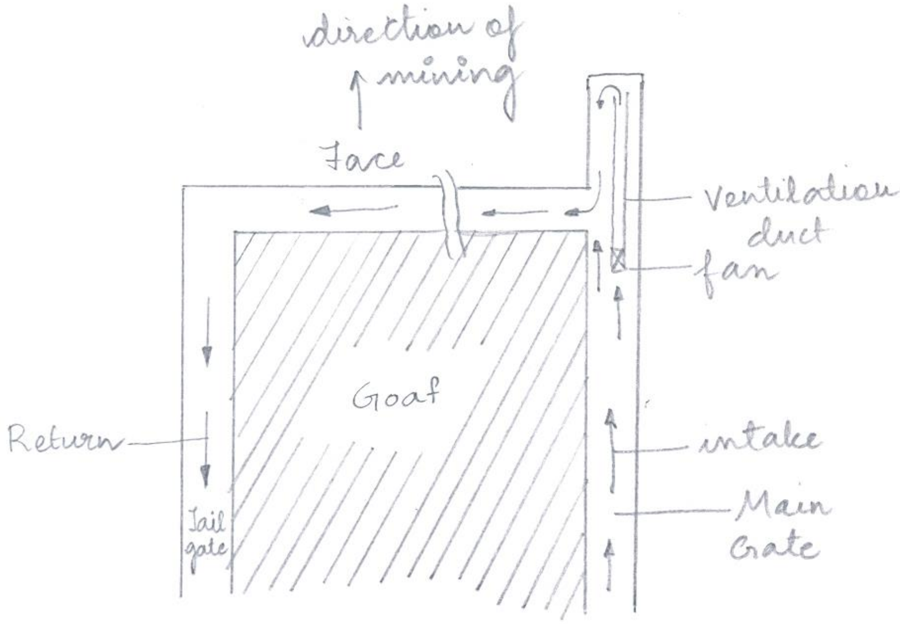

Fig. 3 Layout of ventilation for advancing longwall method of mining (after McPherson, 1993)

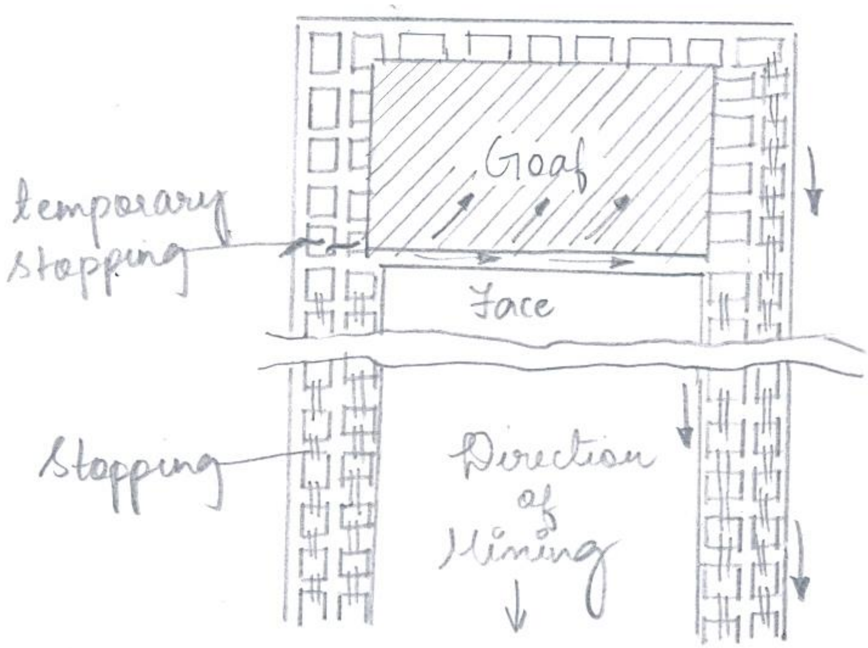

Fig. 4 Layout of ventilation in retreating longwall method of mining (after McPherson, 1993)

2.0 CATEGORIZATION OF VENTILATION SYSTEM IN MINES

The vast network of ventilation system that runs throughout the underground mines can be divided into three broad categories on the basis of the area covered by them. They are:

- Primary ventilation system or main ventilation system
- District system
- Auxiliary system

The first one runs throughout the mines, the second one, in districts or workings or panels and third one in the areas with blind openings. By blind openings, we mean an opening in underground that has only one open end and the other end is closed.

3.0 ELEMENTS OF PRIMARY VENTILATION SYSTEM

These elements or components are the characteristics of any ventilation system and are must for their proper functioning. These are the components which along with the efficiency of ventilation are also responsible for quality management of air supply.

3.1 Downcast and Upcast

Downcast is the entry gate for fresh air from the atmosphere i.e. surface to the underground. Downcast can be in the form of a shaft, an incline or an adit. On the other hand, upcast can also be anyone of these, but it serves just the opposite function i.e. it is an exit gate for polluted air from the mine to the surface. Please note that we have mentioned fresh air in case of downcast and polluted air in case of upcast. Do you find any reason for this? No doubt, there is a reason behind this. In the course of fresh air being supplied to different workings, it is added up with methane, coal dust, fumes, dust and other noxious gases. Hence, ventilation engineer also has to look into the quality aspect of the air.

3.2 Intakes and Returns

The network of airways running from the bottom of downcast to different workings in underground are termed as intakes and the network of airways that run from different workings to the bottom of the upcast are termed as returns. The former carry the fresh air or air to be used up, while the latter carry the polluted air after being used.

3.3 Fans

Before coming to the location and types of fans used in ventilation system, you may be interested in knowing, "why do we need a fan?" It is important to mention that, it is the pressure difference, which is a must condition for air to flow in mines. The necessary pressure for air to flow in mines is built up by providing a surface fan. Now the types of fan we can make use of depends on the way in which we want to create this pressure difference (Fig. 5).

The types of fan used for underground ventilation can be

- Forcing type (push system)
- Exhausting type (pull system)
- Push-pull type (a combination of the above two)

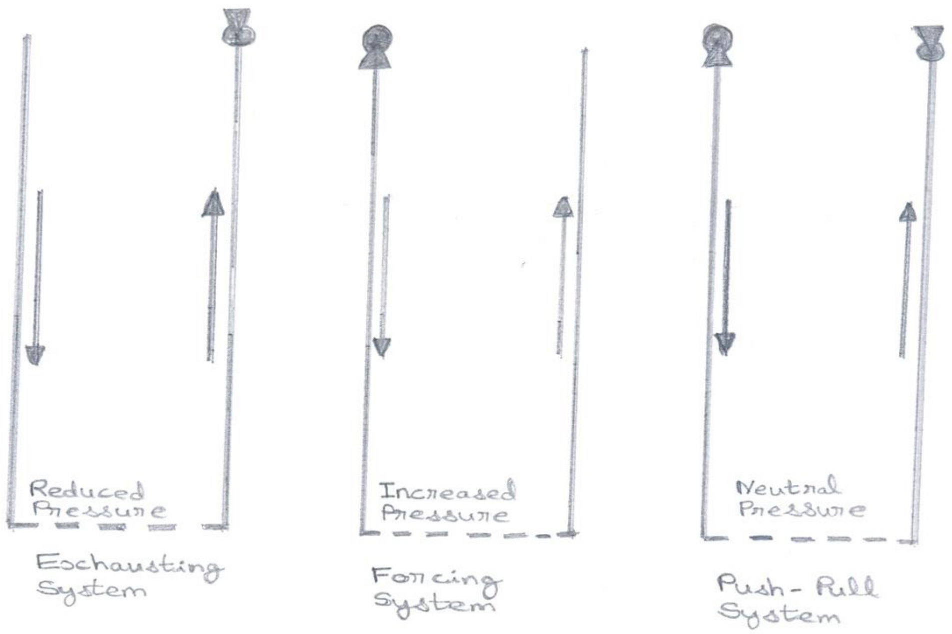

Fig. 5 Different possible locations of main mine fan (after McPherson, 1993)

The forcing fan is generally located on the surface near downcast side or at the bottom of the downcast and it forces air from the atmosphere to underground. The second one i.e. the exhausting type of fan is located either on the surface near upcast side or at the bottom of the upcast. It sucks air (polluted air) from underground and releases it to the surface via upcast.

The push-pull system is a combination of both forcing and exhausts types. It is generally used in metallic mines and is very advantageous as it maintains neutral pressure in underground with respect to the surface and minimizes or reduces the degree (amount) of air leakage in the course of travelling (after McPherson, 1993).

Before we come to the advantages and disadvantages of forcing and exhaust systems of ventilation, we should first discuss about the location of the fan in the ventilation network. In most of the cases it is on the surface and may be a mandatory condition in case of coal mines. This is for the purpose of better performance, safety, maintenance and lower cost. Location on the surface has got advantages in terms of installation, testing, maintenance and access as on the surface, we can make use of space. On the other hand, in underground we cannot as the space is restricted and confined. In case of an emergency situation like explosion, etc, the surface location of fan is always advantageous. Further, when the fan is located on the surface, it does not have to deal with problems posed by doors, airlocks and leakage routes existing in mines, as opposed to fan located underground.

3.4 Choice Between Forcing and Exhausting Fan System

The choice of a fan system is made after assessing the advantages and disadvantages of each system. However in most of the mines exhausting type of fan is used. Whether to go for forcing or exhaust fan, is based on various parameters which are given in Table 1.

Table 1 Various parameters favoring use of forcing or exhaust fan

Parameters	Exhausting fan	Forcing fan
Strata gas control i.e. the gas emitted from the strata	Stopping of exhaust fan increases the pressure with respect to the pressure which was maintained during its running time and compresses the accumulated gas because of which it prevents peak gas concentration in air streams. Upon restarting the fan, they expand because of reduction in pressure, but not up to the extent caused by stopping of forcing fan.	Its stoppage causes rapid decrease in pressure with respect to the existing one when the fan was running, and hence gas emitted from the strata expands rapidly, reaching the peak level in the air stream.
Maintenance	Dust, water droplets and other pollutants in the exiting air corrodes the impellers.	Deals with fresh air and thus require less maintenance.
Transportation	Preferred when transportation is done via downcast.	Preferred when transportation is done via return airways and upcast.
Performance factor	Generally air, dealt in this case is warmer and lighter as compared to that of forcing fan. This results in more volume of air flow for same pressure difference. It recovers some of the kinetic energy of exiting air through expanding evasees fitted to it.	Deals with cooler and denser air and thus less volume of air flows for same pressure difference. It is fitted with inlet grilles (to prevent small birds or solid particles entering the mine along with air) that absorbs some of the available energy (lost due to friction). It also increases the temperature of incoming air because of compression.

The above comparison indicates that exhausting type of fan is more suitable for use as a main mechanical ventilator.

Now, the question arises, if we don't use fans, whether there will be any flow of air or not? If there exists flow of air even without fan, what are the factors responsible for such a flow? It is important to know that, the psychometric properties of intake air and return air are not the same. They differ in terms of humidity and temperature. The intake air is cooler and less humid compared to return air. The return air is warmer due to heat added to air in course of its travel in underground mines. This heat is added from strata, men, machinery, explosives and many other sources. Also water vapor is added to the air in its course of travel. This leads to an increase in humidity. It is important to know that the specific gravity of water vapor is 0.622. Thus, water vapor addition lowers the density of air. We all know that warmer air is lighter than cool air. Hence, overall effect can be taken as decrease in density of the return air.

We know that -:

$P= \rho g h$

where p= pressure, ρ= density, g= gravitational constant and h= difference in elevation

Thus pressure difference can be created if density changes. This pressure difference created due to change in density causes the air to flow. This is called as natural ventilation. The ventilation system supported with fan is called MECHANICALVENTILATION. Natural ventilation may be supportive or resistive to mechanical ventilation depending on the direction of pressure differential.

3.5 Stoppings and Seals

Stoppings are used to avoid mixing of air between the intakes and returns. They can be of two types i.e., temporary and permanent. Temporary stoppings are very common in coal mines whereas permanent stoppings are common is metal mines.

Temporary stoppings are usually of brattice cloth. Sometimes they are just hung across a roadway so that it allows access for men and material. Sometimes they are fixed firmly across the roadway with the help of wooden frames.

Permanent stoppings are made up of brick or cement material. To built a permanent stopping, a proper foundation is necessary so that it is firm and does not allow leakage of air to take place. This is done by making recess cuttings all around the roadway at the construction site of the stopping. Attempt should be made to see that the foundation starts from un-fractured ground (to avoid leakage of air). As per Coal Mines regulation in India, the stoppings which are constructed between the main intake and return should be constructed with bricks with minimum thickness of 250 mm. Further, these stoppings should be plastered by lime or cement mortar. For explosion proof stopping, the Directorate General of Mines Safety recommends 1.5 m thick brick wall. The fireproof or explosion proof stoppings in coal mines are generally made of two brick walls (each brick wall two brick thick) or concrete. The intervening space between these walls is filled with noncombustible waste material.

Seals are similar to stopping except that they are used to block working area from abandoned area. This is done to utilize air in areas where it is needed.

3.6 Doors

The concept of doors is similar to that of stoppings. We built doors again to avoid mixing of intake and return airs. Many a time's stoppings are also provided with access doors. The basic difference between a door and a stopping is that, we want an access between intake and return in case of a door, while no access is required in case of stopping. Doors are made of steel or wood and they are constructed in such a way that they open towards higher air pressure side. They also have self-closing feature which is incorporated during construction stage itself. This feature can be achieved by installing the frame of the door at an angle of 10° with the vertical. Due of this, the door closes on its own because of its weight. Rubber strips are attached along the bottom of the doors to avoid leakage. Sometimes steel or other light metal doors are used in mines where the problem due to corrosion is negligible. Infact, metal constructions are preferred for fire doors. The fire doors are normally kept open but are shut in case of a fire in order to prevent air reaching the fire area. The Indian Coal Mines regulation requires that the thickness of the concrete wall in which the door frame is set should not be less than 250 mm.

Now, let us assume a situation where in the direction of pressure gets reversed across the doors. Do you think it will cause the doors to open? This does not happen as the doors are hinged in such a way that they do not open in the other direction. Sometimes they are also provided with latches. A latch does not allow them to open in case of an emergency like reversal of direction of air current.

3.7 Airlocks

An AIRLOCK is formed when two or more set of doors are installed between main intakes and returns. The purpose of providing an airlock is for a better safety against short-circuiting of intake and return air whenever one door is opened for passage of persons or transportation of machinery/equipment etc. That is the reason why, the distance between the two doors forming an airlock is governed by the longest train of tubs/vehicles available in mine for transportation.

Pressure on a single door should not be allowed to exceed 250 Pa, whereas on airlocks, pressure upto 500 Pa can be provided. Above this pressure, it becomes difficult to open the doors. If pressure above 500 Pa is expected on the airlock, such airlocks are provided with a shutter with adjustable opening (On both the doors). By opening the shutter, we will be able to equalize the pressure across the doors and therefore it becomes easier to open the doors.

3.8 Regulators

Do you wonder why regulators are provided in a fan (at home) or in a cooking gas cylinder? The idea is to have a control (in case of fan, air velocity and is case of cooking gas cylinder, gas flow rate) as our requirement is not the same all the time. In case of mine ventilation, the purpose of regulator is the same. In some areas we need more quantity of air and in some areas we require lesser depending on number of men working, size of the district, machinery deployed, gas emission, comfort level etc. Depending upon the work a regulator can perform, it is classified into two types namely passive and active regulators.

3.8.1 Passive regulator

It is used to serve the purpose of decreasing the airflow, or in other words quantity. In some situation we cannot change the pressure difference and hence velocity remains unchanged. Thus to reduce the flow, we need an arrangement that would vary the area of cross section depending on the requirement. Thus, it can be thought of as a door or a stopping fitted with an opening, the area of which can be varied by some sliding mechanism. In general, passive regulators are rectangular openings which are partially closed by a sliding panel. They are generally placed in the return.

3.8.2 Active regulator

It is just the reverse of passive regulator. Here we need to increase the quantity of air to be supplied. The quantity of air can be increased either by increasing the air velocity or the cross-sectional area. Now, let us consider a situation where we cannot change the maximum allowed cross sectional area. Therefore, for increasing the rate of flow, we are left with an option of increasing the air velocity only. This can be done only if we increase the pressure difference in that area (locally). This pressure difference can be increased by installing fans (called "booster fans" which will be discussed in mechanical ventilation). The installation and control of the booster fan should be such that leakage of gases or any undesirable recirculation i.e. polluted air going back to the face again is avoided.

3.9 Air Crossings

Let us consider the situation where intakes and returns have to cross each other. We also want that there should be no mixing of intake and return air. In this situation we take advantage of difference in temperature and density of the fresh air and return air. The return air is warmer and less denser and will move upwards easily. Thus air crossing can be thought of as an arrangement that would elevate the horizon of return airway above the intake airway.

Now, we come to the end of main ventilation system. Can you tell which of the following air will have more flow – one at 50% humidity or the one at 80%? Does humidity has any role to play in the flow of air. We all know that density decreases with increase in humidity. Thus by using the relation

$$v = \sqrt{\frac{2 \times \Delta p_v}{\rho_{air}}}$$

where v = velocity of air (m/s), Δp_v = change in velocity pressure (Pa), the velocity increases thereby causing more flow of air (The details of the expression given above will be dealt in detail in ventilation survey).

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