LECTURE – 1

THE CONTENTS OF THIS LECTURE ARE AS FOLLOWS:

1.0 AIRWAYS CONNECTED IN SERIES AND PARALLEL

It is very weird in the field of mining engineering to come across words such as 'series' and 'parallel'. We have already studied about series and parallel electrical circuits in our lower classes and the applications associated with them. Now how do these terms have significance in mining operations ?. Before we begin to discuss about these topics, we must have some overview about ventilation in underground mines and its necessity. What is ventilation then?

Ventilation is a process of providing an appropriate flow of fresh air along working places. The primary purpose is to provide oxygen for mine workers but it is also essential -:

- To dilute the concentration of explosives and toxic gases to environmentally safe levels and the removal of them from the mines.
- To create conditions suitable for the workers in which they are able to acclimatize themselves.

To achieve the required conditions of ventilation in a mine, arrangements are made for a suitable path or paths (normally called airways) for the air to flow down the mine to the working places and suitable routes when it has become unsuitable for further use. Thus, a proper planning of the distribution of airflows together with the location of fans and other ventilation controls play a crucial role to achieve acceptable environmental conditions. In any operating mine, new workings are continually developed with time and older ones come to the end after their productive life. So , a proper analysis of the ventilation network becomes very important.

Therefore, while carrying out ventilation network analysis, an interactive behaviour between different airways is studied and the best possible paths for the flow of air are developed. After detailed analysis and experience, it was found that connection of airways is analogus to series and parallel electrical circuit. Thus in a ventilation system two basic combination of airflows are possible which are employed in underground mines-:

- Airways connected in series

- Airways connected in parallel

1.1 Airways Connected in Series

A series ventilation circuit is one in which the air is first used in one workplace, then directed to another workplace and then potentially reused in many other workplaces. It has also been variously described as "cascade" ventilation or "daisychaining". Reuse of air via series circuit design should not be confused with recirculation, which is where the same air is used twice in the same workplace.

Series ventilation circuits have become very popular in many if not the majority of hard rock mining operations in Australia over the past several years.

The flow of air in a series airway can be easily compared to that of an electrical circuit connected in series. We know that electrical current flows through a branch if there exists a potential difference between the two ends (Ohm's law). Similarly airflow through an airway results from difference of pressure between the higher pressure end at the inflow and the lower pressure at the outflow end. Even the Kirchhoff's laws of electric circuit are valid in case of airflows. The understanding of series airways can be achieved by making the following assumptions -:

Current = Quantity of air or volume flow rate (Q) in m^3/sec

Resistance (R) = Resistance offered by airway (R) in Ns^2m^{-8}

Voltage drop (V)= Pressure drop (P) in Pa

Some specifications of a series circuit are -:

- The quantity of air flowing through each airway is same i.e $Q = Q_1 = Q_2 = Q_3$ (Please refer Fig. 1)
- The total pressure drop across A and B (Fig. 1) is equal to the pressure drop across airways 1 ,2 and 3 i.e., $P = P_1 + P_2 + P_3$

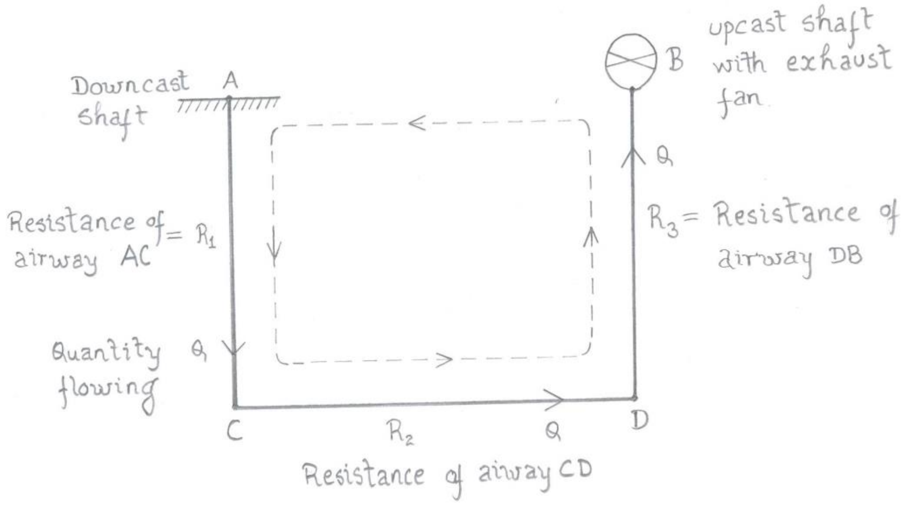

Fig. 1 Resistances connected in series (after Hartman et al., 1982)

According to Atkinson's equation we know that –:

$$P = R\,Q^2$$

As we know that for series connection, $P = P_1 + P_2 + P_3$

Now, let us assume that the equivalent resistance of the airways connected in series for Fig. 1 is R_{eq}. The quantity flowing in all the three airways is the same i.e., Q. Therefore we can write,

$$R_{eq}\,Q^2 = R_1Q^2 + R_2Q^2 + R_3Q^2$$

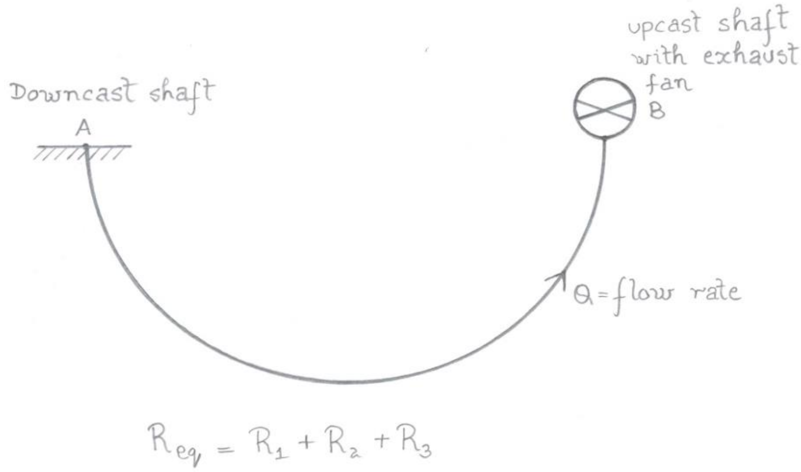

Fig. 2 Equivalent resistance for resistances R_1, R_2 and R_3 connected in series (after Hartman et al., 1982)

Therefore,

$R_{eq} = R_1 + R_2 + R_3$ (Please refer Fig. 2)

In general, for 'n' number of airways connected in series we get -:

$$R_{eq} = \sum_{i=1}^{i=n} R_i$$

In case of series airway each working district can have further connection of roadways in series according to the air requirement in a particular region. Thus there can be many links of series airway within various working district of a mine as shown in Fig. 3.

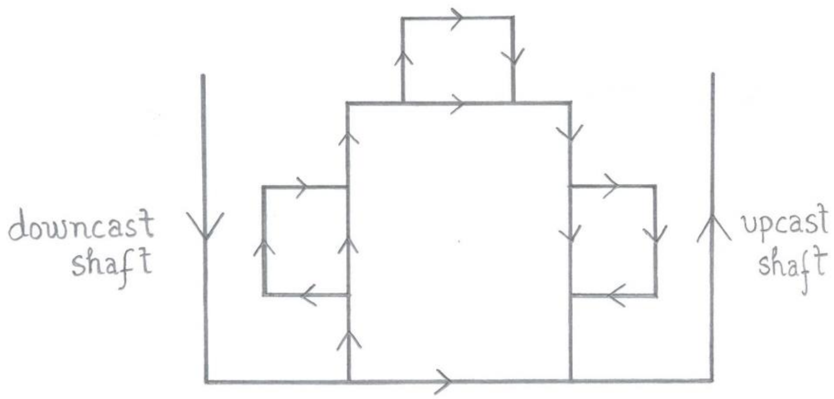

Fig. 3 Sketch showing series connection in each working district (after Hartman et al., 1982)

1.2 Airways Connected in Parallel

The other major system of ventilation circuit design is parallel circuits, also known as "one pass" or "single pass" ventilation. In parallel designs, air is used in one workplace and then directed to the return.

Airways are said to be connected in parallel when the airways branch at one point and rejoin at another. In this case, the pressure drop, P, is common to each parallel airway. Some specifications of a parallel circuit are (Please refer Fig. 4)-:

- The sum of the quantity of air flowing in each airway is equal to the quantity of air flowing in intake airway i.e $Q = Q_1 + Q_2 + Q_3$

- The pressure drop across each airway is same i.e., $P = P_1 = P_2 = P_3$

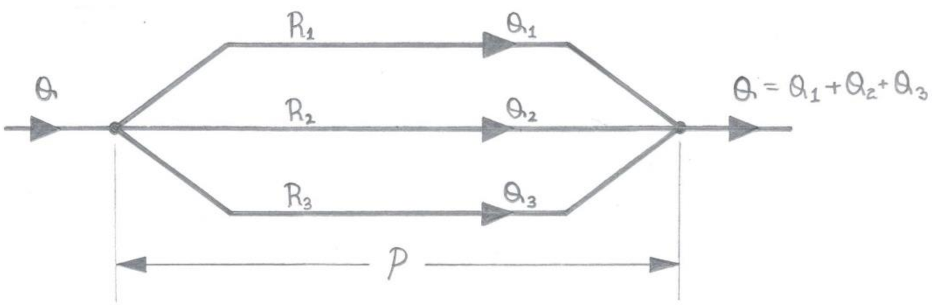

Fig. 4 Resistances connected in parallel

According to Atkinson's equation we have -:

$$P = RQ^2$$

Now, let us assume that the equivalent resistance of the airways connected in parallel for Fig. 4 is R_{eq}. The quantity flowing in all the three airways is different, but the sum total of all the quantities is equal to Q. Therefore we can write,

$Q = Q_1 + Q_2 + Q_3$

$$\sqrt{\frac{P}{R_{eq}}} = \sqrt{\frac{P}{R_1}} + \sqrt{\frac{P}{R_2}} + \sqrt{\frac{P}{R_3}}$$

$$\frac{1}{\sqrt{R_{eq}}} = \frac{1}{\sqrt{R_1}} + \frac{1}{\sqrt{R_2}} + \frac{1}{\sqrt{R_3}}$$

$$R_{eq} = \left(\frac{1}{\frac{1}{\sqrt{R_1}} + \frac{1}{\sqrt{R_2}} + \frac{1}{\sqrt{R_3}}}\right)^2$$

In general for 'n' number of airways -:

$$\frac{1}{\sqrt{R_{eq}}} = \sum_{i=1}^{i=n} \frac{1}{\sqrt{R_i}}$$

Let us assume that there are four airways which are connected in parallel. The combined characteristic of the four airways connected in parallel is shown in Fig. 5 along with their individual characteristics.

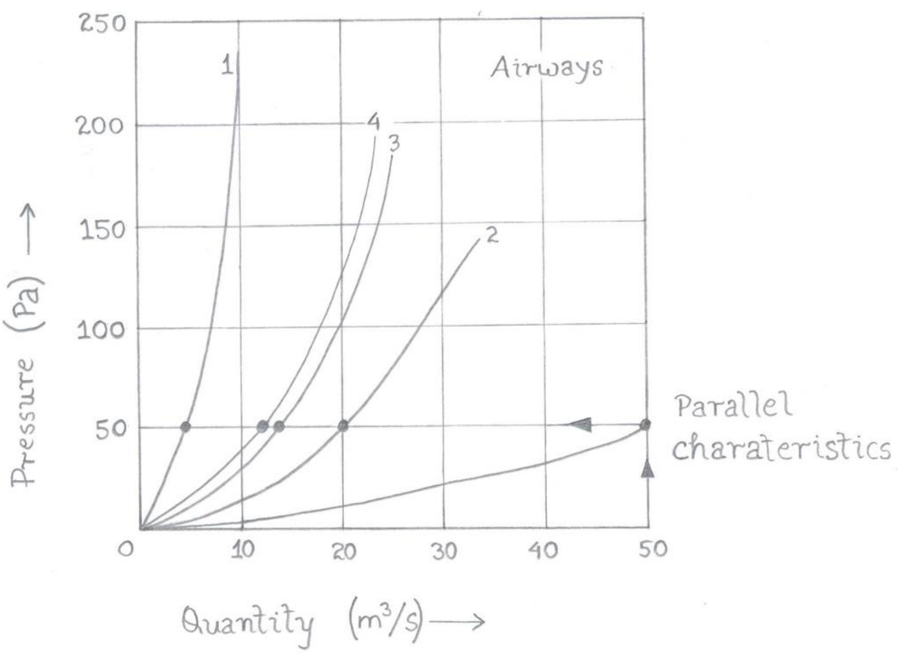

Fig. 5 Combined parallel characteristic of airway 1, 2, 3 and 4

Fig. 6 shows further splitting of airways in every working district of Fig. 4.

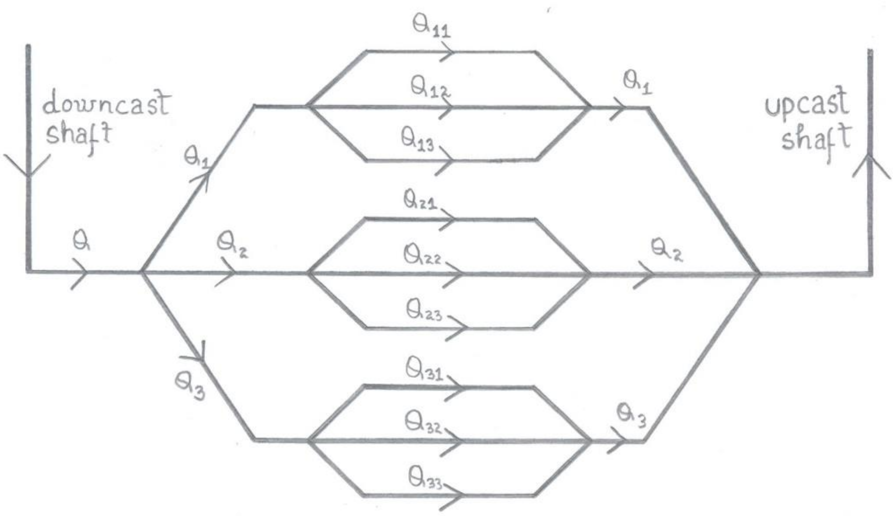

Fig. 6 Sketch showing further splitting in each ventilating district

1.3 Ratio of Resistances of Series and Parallel Airways

- The equivalent resistance in case of series connected 'n' number of airways when all have equal resistances is $R_{series} = nR$

- The equivalent resistance in case of parallel connected 'n' number of airways when all have equal resistances is $R_{parallel} = R/ n^2$
- RATIO = $R_{series} / R_{parallel} = n^3$

Thus the equivalent resistance in case of series connection is n^3 times the resistances connected in parallel.

The concept of equivalent resistances is particularly useful to combine two or more airways that run adjacent to each other. Through such means, the several thousand actual branches that may exist in a mine can be reduced to a few hundred, which simplifies the circuit and reduces the amount of to be handled, and also minimizes the time and cost of running network simulation packages.

2.0 SPLITTING OF AIRWAYS

Splitting of airways is the same as parallel connection of airways in which the main intake airway from the downcast shaft is splitted into 2, 3 or more airways in order to supply fresh uncontaminated air in each and every district according to the respective quantities needed in these districts (Fig. 7). Splitting as a means of distributing air from the shaft to the face was first adopted by John Buddie in 1810 in the coal mines of U.K. Splits reduce the overall resistance of the mine and increases the fan quantity. There are two forms of splitting:

- **Natural splitting** occurs when the quantity of air is divided among the parallel branches of its own accord without regulation.
- **Controlled splitting** occurs when a prescribed quantity of air is made to flow through each parallel branch by means of regulation. Controlled splitting in a parallel flow is achieved by creating artificial resistances in all except one of the branches of the circuit. The branch without an artificial resistance is termed as free split. Devices called regulators, which causes alternate contraction and expansion of the air, are used to create artificial resistances.

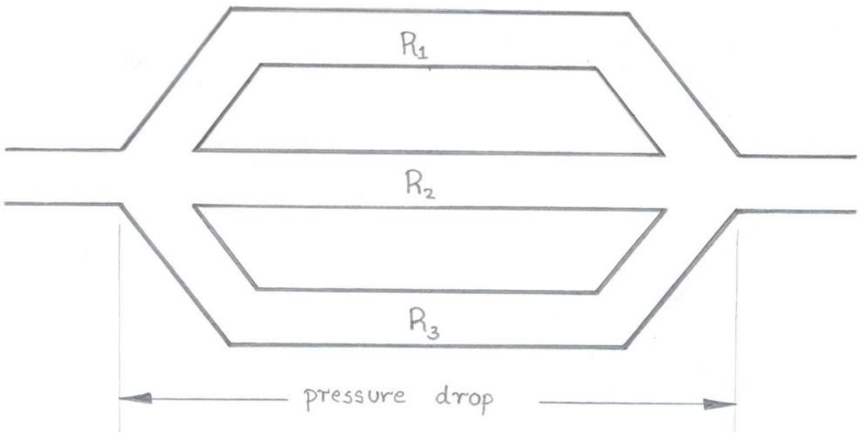

Fig.7 Sketch showing typical splitting of airways

2.1 Merits

- Controlling the flow of air is possible by installing regulators.
- In case of fires/explosions in one panel, the production /operations in other panel is not affected.
- Each district is supplied with fresh air. Therefore the percentage of methane in any district is small.
- Air velocities get reduced, so there is less friction and dust.
- They are effective, more flexible and safer when it comes to clearing of fumes after blasting.
- They provide fresh air at every working place of a district.
- The overall mine resistance is lower, thus air flows with much ease.
- Larger quantity of air can be circulated for the same pressure and power. In other words, for the same quantity, there is saving in the ventilation cost, as splits being in parallel have lesser effective resistance.
- Leakage of air can be minimized by adjusting pressure across various districts suitably. This is very important in seams liable to spontaneous combustion and also where there are sealed off fire area.
- Better control on air velocity is possible as quantity of air is not the same in each split.

2.2 Demerits

- Necessity of maintaining a large number of airways.

- Since the air velocity is decreased, the air picks more heat from the surrounding strata by virtue of a larger contact time with the rock surface and create uncomfortable conditions .
- Ventilation network is more complex due to many splits using Ventilation Control Devices (VCDs), in particular regulators.
- They are more susceptible to leakage or recirculation.
- If the number of splits are too large then it produces sluggish ventilation at the face .

3.0 MERITS AND DEMERITS OF SERIES AIRWAYS

3.1 Merits

- It uses air more efficiently as it is more used up in its path.
- Nowadays for higher production we need to go for large development size of airways. Conventionally, it used to be 3m x3m, but now a day's 6m x 6m is more commonly used in many parts of the world. In this case series connection is advantageous as we can maintain the air velocity (since Q= V x A).
- Series circuits are simple circuits as there are no splits.
- There is a lesser need for Ventilation Control Devices (VCD) in particular regulators.
- There are less chances of leakage of air.

3.2 Demerits

- Since the fresh air is not supplied to each district, it results in poor working conditions .
- In case of fire, explosion or any other accident in one panel, the production from the other panels is also disrupted.

REFERENCES

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