UNDERGROUND MINE VENTILATION SURVEY

A THESIS SUBMITTED IN PARTIAL FULLFILLMENT OF THE

REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology

In

Mining Engineering

By

ALOK RANJAN SETHI

111MN0403

DEPARTMENT OF MINING ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY

ROURKELA – 769008

(2014 -2015)

UNDERGROUND MINE VENTILATION SURVEY

A THESIS SUBMITTED IN PARTIAL FULLFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology

In

Mining Engineering

By

ALOK RANJAN SETHI

111MN0403

Under the Guidance of

PROF. D. S. NIMAJE

DEPARTMENT OF MINING ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY

ROURKELA – 769008

(2014 -2015)

National Institute of Technology

Rourkela

CERTIFICATE

This is to certify that the thesis entitled "**UNDERGROUND MINE VENTILATION SURVEY**" submitted by **Sri Alok Ranjan Sethi (Roll No. 111mn0403)** in partial fulfilment of the requirements for the award of Bachelor of Technology degree in Mining Engineering at the National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any Degree or Diploma.

Prof. D.S. Nimaje
Asst. Professor
Dept. of Mining Engineering
National Institute of Technology
Rourkela – 769 008

ACKNOWLEDGEMENT

I wish to express my profound gratitude and indebtedness to Prof. D. S. Nimaje , Department of Mining Engineering, NIT Rourkela for introducing the present topic and for his inspiring guidance, constructive criticism and valuable suggestion throughout the project work.

I am thankful to Mr. A. A. Ansari , ventilation officer at the Nandira Colliery for helping me in completion of my project work in all respects. I am also thankful to Mr. Sunil Kr Singh, alumni of our department currently working as Assistant Manager at Nandira Colliery for helping me with the instruments and permission, special thanks to my brother and parents for their support and help in carrying out.

Alok Ranjan Sethi

CONTENTS

Sl. No.	Topics	Page No.
	CERTIFICATE	i
	ACKNOWLEDGEMENT	ii
	ABSTRACT	v
	LIST OF TABLES	vi
	LIST OF FIGURES	vii
	LIST OF PHOTOGRAPHS	viii
1	INTRODUCTION	1-2
1.1	Background	1
1.2	Objectives	2
2	LITERATURE REVIEW	3-4
2.1	National status	3
2.2	International status	4
3	VENTILATION STANDARDS	5-7
3.1	Indian standards	5
3.2	International standards	6
4	UNDERGROUND MINE VENTILATION SYSTEM	8-17
4.1	Air flow principles	8
4.2	Air distribution in different coal mining methods	8
4.2.1	Bord and pillar method	8
4.2.2	Longwall method	8
4.3	Types of ventilation systems	9
4.4	Other ventilation system	10
4.5	Equivalent orifice	12
4.6	Mine resistances	12
4.6.1	Laws of mine air friction	13
4.7	Mine system and control devices	13
5	METHODOLOGY	18-37
5.1	Air quantity surveys	18
5.2	Pressure surveys	18
5.3	Equipment's required for pressure quantity survey	20
5.4	Flowchart for conducting ventilation survey	26
5.5	Ventilation plan	26
5.6	Selection of measurement stations for pressure quantity survey	29
5.7	Procedure for conducting pressure survey by gauge-tube	29
5.8	Measurement of cross-sectional area	30
5.9	Traversing methods	31

5.10	Survey records	35
5.11	Hygrometric surveys	35
5.12	Precautions during survey	37
6	RESULT AND ANALYSIS	38-54
6.1	Result	38
6.2	Analysis	46
7	CONCLUSIONS	55-56
7.1	Conclusions	55
7.2	Recommendations	56
	REFERENCES	57

ABSTRACT

Underground coal mine ventilation systems are particularly complex because of multiple seam working methods which splits the underground air network into different districts or/and panels thereby allowing multiple ventilation methods. In order to gain an understanding of the complex networks incorporated in the system, a coal mine **ventilation survey** is required. The information obtained from this survey is used to determine the most efficient techniques to accomplish any proposed improvements. The proper operation of the ventilation system at maximum efficiency is essential for providing a safe and healthy underground working environment. These systems should be designed to ensure that adequate amounts of ventilating and numerous split air reach each working area. Most underground coal mines in India employ an exhaust (i.e. negative pressure) ventilation system.

This project deals with the pressure and air quantity survey of an underground coal mine ventilation system at Nandira colliery, Talcher. The survey work has been carried out with the help of latest instruments at nearly forty stations. Methodology of the ventilation survey and simulation of survey readings in VENTSIM has been demonstrated. Based on the simulation result, analysis was done.

LIST OF TABLES

Table	Name of the Tables	Page No
3.1.	Recommendations of air velocity	6
3.2.	Permitted air velocities in different roadways	7
3.3	Quantity of air for degree I, II and III gassiness mines.	7
5.1	Instruments for measuring Air velocity in Mines	25
5.2	Number of measuring points on each diameter of a circular duct.	34
6.1	Access to Nandira Mine	39
6.2	Working districts in Nandira Mine	39
6.3	Support systems at Nandira mine.	40
6.4	Ventilation distribution at Nandira mine	40
6.5	Technical specifications of Main Mechanical Ventilator	41
6.6	Field survey readings	45
6.7	Estimation of leakages	48
6.8	Velocity analysis in branch nodes	53

LIST OF FIGURES

Figure	Name of the Figures	Page No
4.1	Room and pillar development with line brattices to regulate airflow in conveyor belt entry.	9
4.2	Possible locations of main fans	12
4.3	Leakage and resistance in stoppings	15
5.1	Instrument’s needed to conduct a ventilation survey	21
5.2	Components of a Dial vane Anemometer	21
5.3	Pitot - static tube	23
5.4	Flowchart for conducting ventilation survey	26
5.5	Prescribed symbols for ventilation plans	28
5.6	Path of a moving anemometer traverse	32
5.7	Measuring points for a fixed point traverse in a rectangular opening.	33
5.8	Measuring positions for an 8 point traverse on 4 diameters of a circular duct	34
6.1	Ventilation plan layout	43
6.2	Schematic diagram of ventilation systems with nodes.	44
6.3 (i)	Ventsim model design of the ventilation network of the coal mine	49
6.3 (ii)	Simulated model design of the ventilation network of Nandira coal mine	50
6.4	Characteristics curve of MMV	51
6.5	Fan characteristic curve and operating point	51
6.6	Comparison of field studies and Ventsim results.	52
6.7	Correlation analysis of field studies and Ventsim results.	53

LIST OF PHOTOGRAPHS

Plate No.	Name of the Photographs	Page No
5.1	Dial-vane anemometer	21
5.2	An inclined-tube manometer	22
5.3	Sling Psychrometer	24
6.1	Auxiliary Fan	42

CHAPTER 1
INTRODUCTION

1.1 BACKGROUND

In underground mines, production, productivity, health and safety of workers rely upon environmental conditions existed at the work place. Polluted environment reduces the environment efficiency of work persons and machinery which ultimately reflects on the economy of the mine. Proper ventilation of mine workings can lead to safe and efficient operation in mines. So it's essential to conduct a ventilation survey at frequent intervals to monitor the change in environmental conditions and improving it for working.

A ventilation survey is a framework of collecting data that measure the distributions of airflow, pressure and air quality all through the principle stream ways of a ventilation framework which involves a detailed precision of measurement. The examination is generally done for finding the efficiency of a ventilation system, types and the extent of leakages and the steps indispensable for further change. The types of ventilation surveys generally involves [13]

1. *Quantity surveying:* this involves the measurement of the air velocity and the quantity of air flowing in various parts of the mine.
2. *Pressure surveying:* this involves the measurement of the differential pressure drop across the branches in mine.
3. *Qualitative surveying:* this involves the determination of the free damp content at different strategic points in the mine and chemical analysis of the air samples.

The importance of a systematic and regular ventilation survey provide the basis for:

(a) Checking and supply for adequate quantity of air to any working face most importantly in hot, humid and gassy mines.
(b) Detecting and remedying leakages of air.
(c) Determining size of the airways and sections of high aerodynamic resistance
(d) Suggesting possible modifications and alterations in amount and path of air currents, airways resistances, control devices for improving the ventilation efficiency in the mine.

(e) Planning suitable ventilation to control mine fires and with other emergencies such as explosions, major falls etc.
(f) Planning future reorganizations of the ventilation system for extended/modified workings.
(g) To check the standard limits be well maintained for direction and quantity of air in the air flows by the concerned authorities.
(h) Identifying suitable locations for installation of booster fans.
(i) Maintaining an uptodate plan.

1.2 OBJECTIVES

A major objective of ventilation surveys is to obtain the frictional pressure drop, P, and the corresponding airflow, Q, for each of the main branches of the ventilation network. From these data, the following parameters may be calculated for the purposes of both planning and control:

- Distribution of airflows, pressure drops and leakage
- Airpower (P x Q) losses and, hence, distribution of ventilation operating costs throughout network
- Volumetric efficiency of the system
- Branch resistances ($R = P / Q^2$)
- Simulating an effective model for the exiting ventilation system.

CHAPTER 2
LITERATURE REVIEW

2.1 INTERNATIONAL STATUS

Rowland (2011) have demonstrated the ventilation survey techniques and the execution of a ventilation modelling out of the survey results and suggested some outputs for the same. He have emphasized that the level of survey detail required is totally dependent on the end use of the data and the accuracy of the data set for safety and viability of working operations. He formulates a strategy to carry out the appropriate ventilation survey and highlights the nature of report outputs. He had advocated for fabrication of a properly tuned ventilation model which are intricate components of the modern underground safety management systems and emphasis for utilizing the ventilation modelling software as a key tool in ventilation circuit designs and ventilation changes.

Brian & Loomis (2004) have measured the frictional pressure differential during a ventilation survey. They compares the two basic methods of frictional pressure drop measurements; the barometer and the gauge & tube regarding applicability and conditions favoring each method and believed that in both metal and coal mines the gauge & tube method is more preferable than the barometric pressure techniques owing to rapid evaluation and more accurate results.

Hinsley (1966) demonstrated that when a ventilation system is changed from forcing to exhaust the inbye portions of the workings are reduced below the barometric pressure of the air by an amount equal to half the fan pressure.

Akande et al. (2013) developed a model for the calculation of mine airflow distribution as a part of comprehensive study for underground coal mine of Okaba coal deposits. Calculated the air pressure, fan power and airflow rate to maintain the safety levels of methane in underground mine for workers protection against harmful substances.

Calizaya et al. (2010) computed quantity and pressure readings for monitoring and developing a booster fan selection method.

2.2 NATIONAL STATUS

S K Ray et al. (2002) carried out pressure quantity survey on 1 & 2 incline of Jhanjhra area of Raniganj coalfields at RVII & RVIIA seam by hose & trailing method, inclined manometer, pitot tubes etc. and quantity by anemometer at more than 20 strategic locations to ascertain air quantity distribution in mine for introducing a chamber method of ventilation arrangement which is superimposed on main ventilator system to reduce cumulative pressure in a desired area without affecting the main fan pressure and ventilation in other part of the mine.

Varma et al. (2009) conducted ventilation survey which comprises of pressure survey, quantity survey, study of performance of main fan and fire area stoppings behaviour as a part of investigation in Sindra Banjara colliery a unit of Sijua area, BCCL on VI seam of pit no.3.

Morla et al. (2012) presented a detailed case study of the pressure survey of the ventilation network and the simulation results of the GDK-11 incline in RG-I area of SCCL for bord and pillar mines with an objective of increasing the ventilation quantity with low operating pressure and effective utilization of main mechanical ventilator and observed that, the alteration of the intake air shaft into a return shaft will increase overall resistance of the mine.

Sahay et al. (2003) conducted pressure survey, air quantity survey, temperature survey, performance study of fans, computer simulation studies and studied pressure behaviour of stoppings at Kacchi Balihari colliery of Bharat Coking Coal Limited (BCCL), India for controlling fire in the sealed panel.

CHAPTER 3
VENTILATION STANDARDS

3.1 INDIAN STANDARDS

The Indian Coal Mining Regulations (CMR-1957) [16], regulation no. 130 (2) requires that:

- In every ventilating district no less than six cubic meters per minute of air per person employed in the district on the largest shift, or no less than 2.5 cubic meters per minute of air per minute of air per daily tonne output, whichever is larger passes along the last ventilation connection in the district.
- At every place in the mine where persons are required to work or pass, the air does not contain less than 19% oxygen, and or more than 0.5% CO_2 or any noxious gas in the quantity likely to affect the health of any person.
- The percentage of inflammable gas does not exceed 0.75 in the general body of the return air of any ventilating district, and 1.25 in any place of the mine.
- The wet bulb temperature in any working place does not exceed 33.5^0C, and where the wet bulb temperature exceeds 30.5^0C, arrangements are made to ventilate the same with a current of air moving at a speed of not less than one meter per second.
- Indian mining laws sub regulation 133(4) of the CMR requires that ventilation surveys be conducted in 1st degree-I gassy mines at least once every 30 days while air quantity surveys in degree-II & degree-III gassy mines are required to be conducted at least once every 14 days.
- Sub regulation 130(2) (v) requires that concentration of noxious and inflammable gases and temperature and humidity to be determined at the working places in mines at least once in 30 days.
- Under sub regulation 145(2), the Regional Inspector of mines may require the mine management to take measurements of temperature, humidity and other environmental conditions as may be specified once at least in every 30 days.

- A ventilation pressure survey is required to be done under sub regulation 132(1) of CMR 1957 before installation of a booster fan in a fiery seam or gassy seam of the second or third degree gassiness.

Table 3.1 Recommendations of air velocity (Source: CMR-1957 Sec 136 (A))

Degree of Gassiness	Place where velocity of air is to be measured	Velocity, m/min
I Degree	Immediate out bye of ventilation connection from face	30
II Degree	i. 4.5 m from any face whether working or discontinued on the intake side of the brattice partition	30
	ii. 7.5 m out bye of the discharge end of an air pipe	15
	iii. At the maximum span of a longwall face	60
III Degree	i. 4.5 m from any face whether working or discontinued on the intake side of the brattice partition	45
	ii. 7.5 m out bye of the discharge end of an air pipe	25
	iii. At the maximum span of a longwall face	75

3.2 INTERNATIONAL STANDARDS

Based on the experience in this country, as well as the standards adopted by other countries like U.K., Poland, and Russia, the following standards with regard to maximum air velocities are recommended.

Table 3.2 Permitted air velocities in different roadways [21]

Location	Maximum Velocity, m/s
Ventilation shafts not provided with winding equipment, fan drifts	15
Ventilation shafts where man-winding is not carried out or, mineral hoisting shafts only	12
Shafts used for man-winding, and haulage roads (other than conveyor roads)	8
Other roadways	6
Conveyor roads, loading points, and transfer points	4
Working faces in development and or depillaring/stoping areas including longwall faces	4

In gassy coal mines of Degree II and III the quantity of air should be more than the minimum stated above and a reasonable figure should be 8m^3/min per person employed. The quantities of air stated above must reach the working faces. As there is leakage from intake to return at the ventilation stoppings, ventilation doors, air crossings, and ventilation air locks on the surface and other places, more air should pass the downcast shaft/incline. Therefore, the quantity of air going down a mine should be as follows (per minute).

Table 3.3 Quantity of air for degree I, II and III gassiness mines.

Gassiness degree (coal mines)	QTY per person in U/G mine	Per tonne of daily output
I	7m^3	3m^3
II & III	8-10m^3	4-5m^3

In metal mines which are not deep like up to 300m, the quantity of air should go down the intake shaft/ incline should be 4-5m^3 per min. for every worker in the underground mine.

CHAPTER 4

UNDERGROUND MINE VENTILATION SYSTEMS

4.1 AIR FLOW PRINCIPLES [3]

The fundamental principles of airflow may be set out as follows:

a. Air flow in a mine is induced by pressure difference between intake and exhaust openings.
b. The pressure difference is caused by imposing some form of pressure at one point or a series of points in a ventilating system.
c. The pressure created must be great enough to overcome frictional resistance and shock losses.
d. Airflows flows from point of higher to lower pressure.
e. Mine ventilating pressures, with respect to atmospheric pressures, may either be positive (forcing) or negative (exhausting).

4.2 AIR DISTRIBUTION IN DIFFERENT COAL MINING METHODS [2]

4.2.1 Bord and Pillar Method

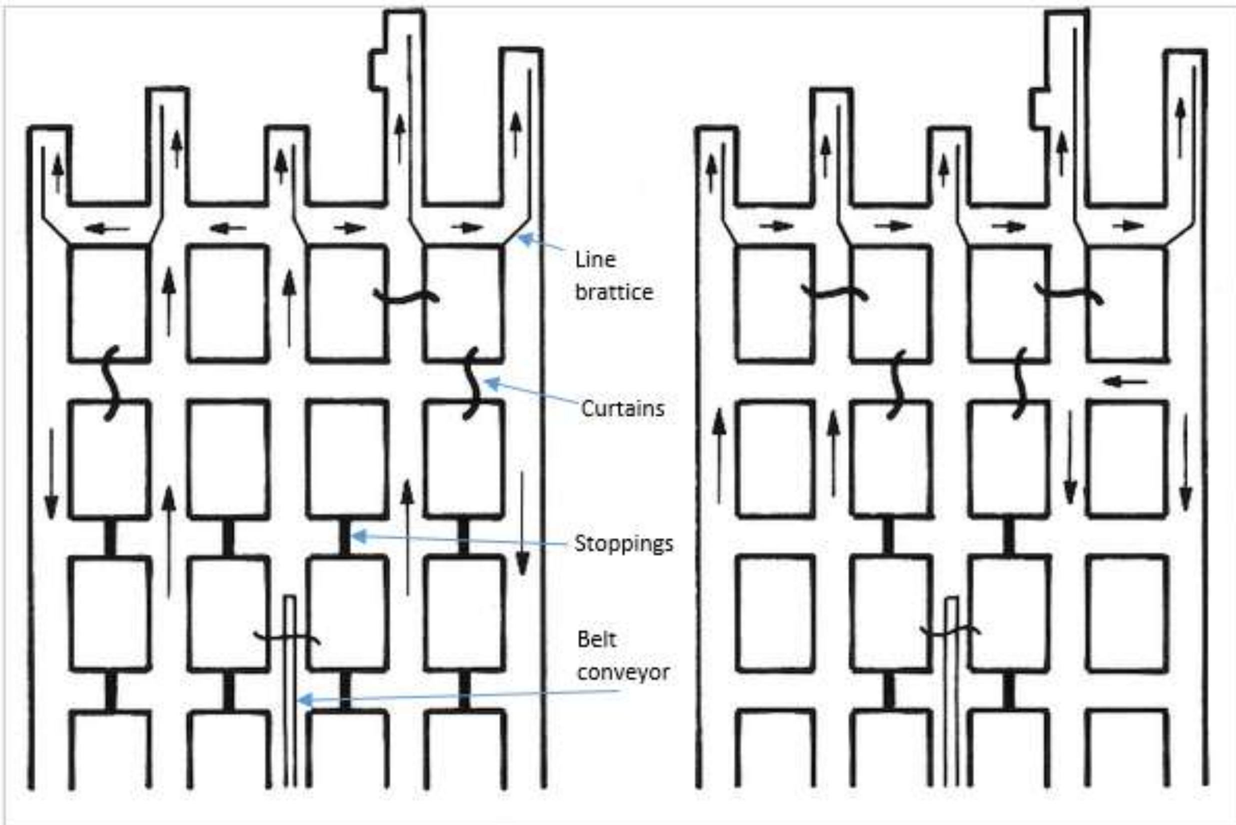
There are a large number of openings in a working district in this method. As a result, the air has to be guided to the working faces by means of numerous control devices such as stopping, doors and air-crossings etc. Air is coursed through the different faces in the working panel with the help of line brattices at the face and temporary stoppings generally made up of brattice curtains in the galleries. However, this results in a substantial leakage through the brattice leading to poor face air velocity. Panels separated by solid coal barriers reduce the number of permanent stoppings and to that extent reduce the leakage.

4.2.2 Longwall Method

Ventilation of longwall faces is easier needing less control. Each face is normally ventilated by a separate split. Leakage is much less in the working district as compared to bord and pillar mining. Longwall workings with hydraulic stowing admit practically no leakage through the goaf, but there is fair amount of leakage across the goaf in longwall caving districts, particularly with advancing faces.

4.3 TYPES OF VENTILATION SYSTEMS

Depending on the relative position of intake and return airways, ventilation systems in mines can be broadly divided into the following:



(a) (b)

Figure 4.1 Room and pillar development with line brattices to regulate airflow in conveyor belt entry: (a) bi-directional system; (b) uni-directional system. (McPherson, 1993)

4.3.1 Boundary or Unidirectional Ventilation System [2]

The boundary ventilation system where the air flows unidirectional from the intake to the return through the workings is by far the most efficient system necessiting the least use of ventilation control devices and thus resulting in a high volumetric efficiency of ventilation (70-80%). It is commonly adopted in metal mines working steep lodes. In the simplest form, the intake and return shafts are located at the two strike boundaries of the mine. Mostly preferable in mines with lower gas emissions. There is no splitting of airway and equivalent resistance R_{eq} is given by the relation:

$$R_{eq} = R_1 + R_2 + R_3$$

4.3.2 Central or Bidirectional Ventilation System [2]

This system is commonly adopted in in-the seam coal mines where both the intake and return shafts are located close by the centre of the property. Intake and return air from any district travel in opposite direction through parallel roadways usually separated by stoppings erected in the cross-connections between them. Also return air from a district has to cross the intake in order to join the main return. The central system of ventilation allows a substantial leakage because of the large number of stoppings and air crossings used so that only 40-50% volumetric efficiency is achieved by these system. Mostly preferable in mines with higher gas emissions. Splitting is mainly of parallel connection and equivalent resistance R_{eq} is given by the relation:

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

4.3.3 Combined Ventilation System [2]

Here in these type of ventilation system the ventilation of development headings is bidirectional in nature while the ventilation of the extraction panels is unidirectional through goaf connected to the return airways called bleeders.

4.4 OTHER VENTILATION SYSTEM [3]

Different types of ventilations are as follows:

i. **Homotropal Ventilation**

Ventilation is homotropal when the ventilation air and the coal flow in the same direction. The return airway in such case is used as the coal transport road to the upcast shaft.

ii. **Antitropal Ventilation**

Ventilation is antitropal when the ventilation air and the coal flow in opposite directions the intake airways then being used as haulage roadways.

iii. Ascensional Ventilation

It implies taking the intake ventilating air to the lowest point of a district or face and allow it to travel to higher levels to ventilate the district or face before it goes to return.

iv. **Descensional Ventilation**

In this system, the air travels downhill from the rise side of a district to the lower levels along the working places and return being at the bottom end of the working place.

v. Exhausting System

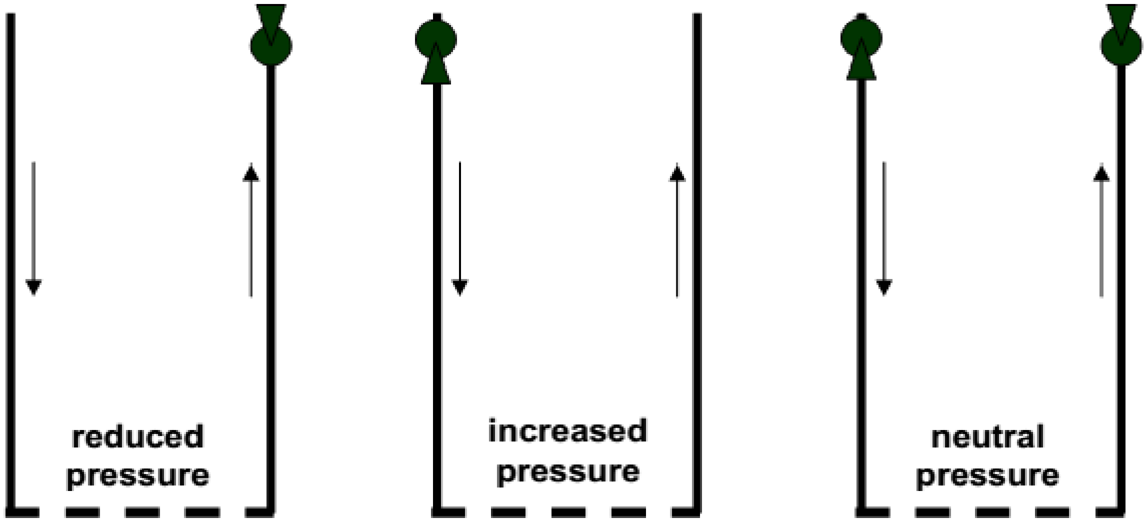
With the exhaust system, the quantity of air available at the face may be sufficient, but unless the duct or tubing is maintained close to the face the velocity may be inadequate to sweep the air across the face. Dust concentration is greatly reduced. Dust and gases are drawn into the duct and discharge into the return air course.

vi. Blowing or forcing system

With a blowing system intake air at high velocity can be directed against the face through a duct. It therefore cannot pick up moisture or dust on its journey to the face and it arrives in a clean dry condition. The method is therefore particularly suitable for wet headings where the rock temperature is high.

vii. Combined Exhaust and Blower system

Using a blower in conjunction with exhaust system provide the advantage of both systems. The system is most suitable for continuous miner faces. The principal advantage of this system is that both the fans be operating to be truly effective.



(a) Exhausting system (b) Forcing system (c) Push-pull system

Figure 4.2 Possible locations of main fans (McPherson, 1993)

4.5 EQUIVALENT ORIFICE

The equivalent orifice of a mine is defined as the area of an imaginary opening in a thin plate which offers the same resistance to the passage of air as is offered by the whole of the mine airways. A mine of high resistance is represented by a small equivalent orifice and low resistance by a large equivalent orifice.

4.6 MINE RESISTANCES

Roadways cause resistance to air movement. The resistance relies on upon the extent of the roadways, perimeter and roughness of the surface in touch with air and also obstruction offered by movement of men and material and supports. The resistance is numerically represented as below:

$$R = \frac{(K \times p \times L)}{A^3} \qquad \text{S.I. unit (Gaul) } (Ns^2/m^8)$$

Where,

A- Area in square metres p- Perimeter in metres

K- Aerodynamic resistance coefficient L- Length in metres

N in Newton, s in seconds, m in metres S.I-Standard International

4.6.1 Laws of Mine Air Friction

The laws which govern the passage of air in the mine are as follows:

Law I : $P \alpha S$ where, S= rubbing surface

= perimeter of airway × length

Law II: $P \alpha V^2$ where, V= air velocity

Law III: $P \alpha 1/A$ where, A= area of cross section

Law IV: $P \alpha K$ where, K= co-efficient of friction

Conditions in which obstructions and disturbances are minimum should be ideally selected for measurement to get a realistic pressure and quantity summary of the mine. Hence it is wise to conduct ventilation surveys while there is no activity taking place likely during on a non-working shift. Mine resistance is often affected by the following reasons:

- Movement of tubs, vehicles etc.
- Falling water in upcast shafts.
- During opening of mine doors.
- Leakage through overcasts or air crossings.
- Movement of personnel's and workers.
- Unexpected environmental changes.

4.7 MINE SYSTEM AND CONTROL DEVICES [2]

A well designed and properly implemented ventilation system will provide beneficial physiological and psychological side effects that enhance employee safety, comfort, health, and morale. In planning a ventilation system, the quantity of air it will be necessary to circulate to meet all health and safety standards must be decided at the outset. Once the quantity required has been fixed, the correct size of shafts, number of airways, and fans can be determined. As fresh air enters the system through the intake airshaft(s) or other connections to the surface, it flows along intake airways to the working areas where the majority of pollutants are added to the air. These include dust and a combination of many other potential hazards, such as toxic or flammable gases, heat, humidity, and radiation. The contaminated air passes back through the system along return airways. In most cases, the concentration of contaminants is not allowed to exceed mandatory threshold limits imposed by law. The return (or contaminated, exhausted) air eventually passes back to the surface via return airshaft(s), or through inclined or level drifts. Air always flows along the path of least resistance, but this may not be where it is required for use. To direct the air where it is needed, ventilation devices are necessary; the primary means of producing and controlling the airflow for the entire system are mine fans (either in the form of single fan installation or multiple fans). In addition, many other control devices also are necessary for effective underground air distribution:

4.7.1 Splitting

In a mine which is having multiple working districts it is always desirable to split the air flow to the sections/districts of the mine where the demand of air quantity arises and requires a separate route for flow. Like the combination of airways in parallel, which reduces their resistance, splits reduce the overall resistance of the mine and increase the air quantity .To control the flow of air to different working districts , the resistance of the split can be varied.

4.7.2 Stoppings

Stoppings are used to block off an old roadway which is no more required for haulage, travelling or ventilation purpose and to create any close connection between the main intake and main return. Every ventilation stopping between the main intake and main return airways in coal mines is made up of either brickwork or masonry of a minimum thickness of 38 cm and suitably plastered by lime or cement mortar to prevent leakage of air. Explosion proof stopping preferable for degree 2 and 3 mines should be atleast 1.5 m thick brick wall. Important fireproof and explosion proof stoppings in coal mines should be made of two thick brick or concrete walls, spaced out a certain distance depending on the strength desired, and the intervening space filled with broken rock, sand and clay, etc.

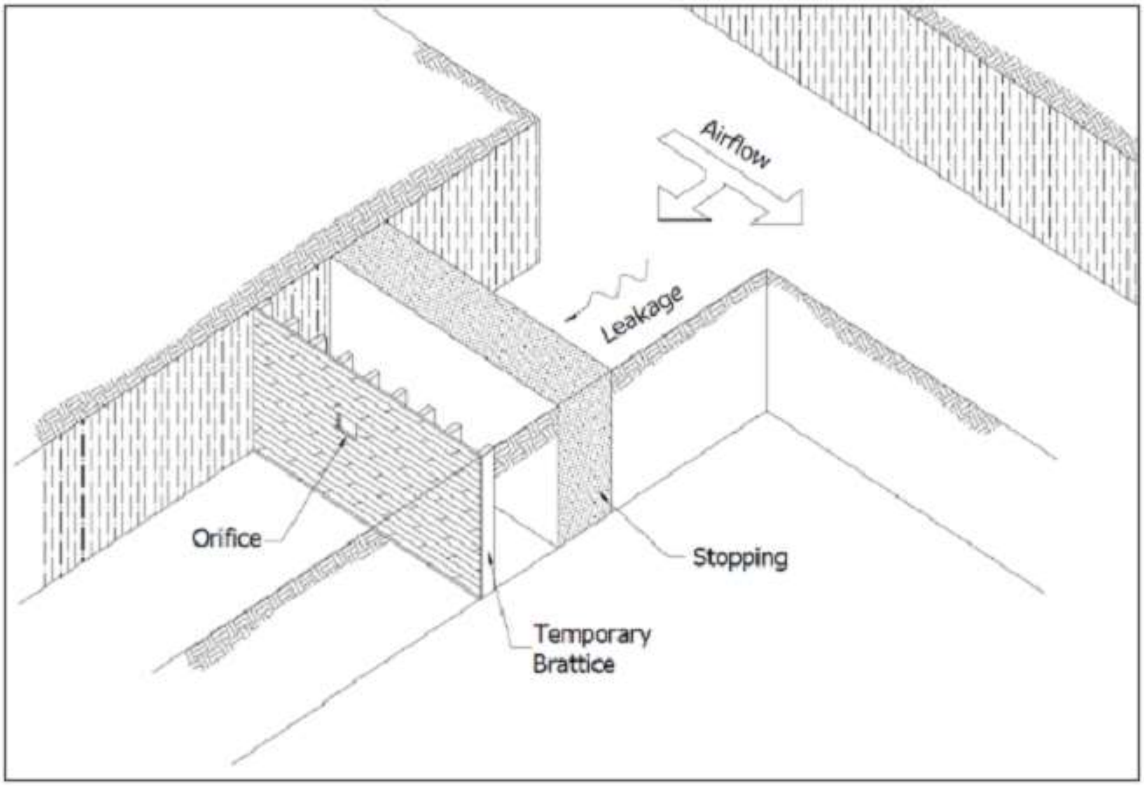


Figure 4.3 Leakage and resistance in stoppings (After Vinson, 1977; from Oswald, 2008)

4.7.3 Air Crossing

As the workings in seam extend it becomes essential to plan carefully the route to be followed by the air current, and in some places it is necessary to pass air along two roads which intersects at right angles. Whenever the return air-current has to cross the intake air-current without mixing with it air crossing is required. An air crossing may be either overcast or undercast according to one airway rises over or dips under the other airway. Because of drainage problems with undercasts, they are not used to any degree. An air-crossing may be temporary or permanent in character. Temporary air-crossings, in which the partitions between intake and return are made of timber or corrugated sheets, or constructed of air-tubes and Permanent air-crossings are required where the strata have settled down and the air-crossing is required for a long period.

4.7.4 Regulator

Regulators are used for the sole purpose of reducing the airflow to a desired quantity in a given airway of the mine. Regulators are usually rectangular opening left in stoppings. In practice the regulator openings are usually provided with a sliding shutter which helps in adjusting the size of the opening to suit the requirements. Regulators can be permanent when they are constructed of steel in a concrete stopping, but more often they are temporary in nature, when they are in the form of an open wooden frame in a stopping made up of brattice cloth nailed on to a wooden frame work. The air quantity can be adjusted by varying the size of the opening by nailing on strips of wood on the side of the opening.

4.7.5 Doors

When access through stoppings become essential then doors are used. Doors should be preferably open on one side, i.e. the high pressure side, opening in the other direction being checked by the frame. Normally, two doors used forming an air-lock so that one is always closed when the other is open. These doors are used as main separation doors near the shafts, whilst one door may suffice near the face.

The door frames are set in suitable air tight stoppings, made of cement concrete and the doors hung from them either vertically or horizontally by means of two or three strap iron hinges. Doors and door-frames must be strong and fireproof in construction. Steel doors for the purpose should have a minimum thickness of 3 mm.

4.7.5 Air locks

An airlock is a set of two doors so installed that one of them is always shut when the other is opened to pass men, tubs or a train. This not only minimizes leakage but becomes essential where the ventilation system is likely to be disturbed seriously by too frequent or prolonged opening of the doors. Indian coal mines regulations require that airlocks should be provided between main intakes and returns. Airlocks should also be provided where the pressure across the door is high.

4.7.6 Brattice Cloth

This is simply a sheet or sheets of canvas hung from props and planks to prevent the short circuit of air from intake to return, so causing the ventilation air to reach the faces. It may be used as a screen across an airway to prevent or reduce the flow of air along it, or as a partition along a roadway to divide it into two parts, intake and return or as hard screen to divert an air current upwards into a roof cavity to clear away any accumulation of gas. Brattice cloth coated with P.V.C is impermeable to airflow, and more suitable for line brattice to ventilate a heading. Brattices should be of fire resistant type.

4.7.7 Booster fans

Booster fans are used sometimes for augmenting ventilation in certain districts. They increase quantity by increasing the pressure causing flow. It is used when the desired increase of the airflow cannot be achieved economically. But it is essential to have a judicious choice of the size of a booster fan because too large a booster in one split can cause stoppage of air current or even reversal of the air current in the other splits.

CHAPTER 5
METHODOLOGY

5.1 AIR QUANTITY SURVEYS [3]

The quantity of air passing through any airway every second, Q is generally given by the expression

$$Q = U \times A \ (m^3/s)$$

Where, U = Velocity of air passing through that point (m/s)

A = Area of roadway (m^2)

Thus to calculate the quantity of air flowing past any particular measuring station, it is necessary-

a) To ascertain the cross sectional area of the passage =A sq. metres.
b) To measure the velocity of air current= V metres per second.

5.2 PRESSURE SURVEYS [3]

The basic principle behind the pressure surveying in a mine is Bernoulli's Theorem which states that, assuming no friction losses, the total pressure or energy of the moving stream of air remains constant throughout a passage of varying cross-section. Let P, is the pressure of air raised by a compressing fan to a total pressure corresponding to a motive column is P. this total pressure is made up of two components- the static pressure of the air (P_S) and its velocity pressure (P_V).The static pressure may itself be regarded as partly the normal atmospheric pressure (static) =H, and partly the static pressure above atmospheric= P_S.

Hence, for a compressing fan, $P= H + P_V + P_S$

And the fan pressure (compression), $p= P_V + P_S$

In an exhausting fan, a depression is created in the fan drift, and the term P_S become negative.

Hence, for an exhausting fan, $P= H + P_V - P_S$

And the fan pressure (depression), $p= P_S - P_V$

Air always flows from a region of higher pressure to lower pressure and, when a mine is ventilated by the surface fan, the maximum pressure is found at the top of the downcast shaft and the minimum pressure in the fan drift at the top of the upcast shaft. The difference (relatively small) between these two pressures represents the pressure causing flow of the air, i.e. the ventilation pressure or water gauge. When the air traverses the mine airways, often kilometers in length, there is a gradual fall of pressure, or pressure drop, from point to point.

The pressure losses are determined either by:

(a) Directly by differential pressure measurement i.e. Gauge and tube method, or
(b) Indirectly by deducing the pressure losses from the absolute pressure difference i.e. Barometric method

Methods of performing pressure surveys

Gauge and the tube method	Barometric method
The pressure difference between the required two points connected by a hose is directly measured on a manometer	The absolute pressure is measured simultaneously at each of the two points using a barometer and the difference between these two absolute pressures gives the required pressure
This method gives accurate results but is time consuming as it involves laying and carrying the hose from point to point.	This method is easy to perform and here is no distance limitation between the two points as no hose is being used.
This method is generally employed in typical coalmines where very high pressure differences are not observed.	This method is preferred in large mines with multi-level workings where high pressure differences are required to be measured.

The choice of instrument for pressure survey depends on the extent of mine workings, the accuracy required, portability of the instrument and time available to carry out the survey. In most Indian mines, the ventilation pressure is very small. It rarely exceeds 25mm to 50 mm of water gauge and in the traverse of the circuit the pressure drop for a short section of airway is small. Pressure survey is made by the various types of pressure measuring instrument including:

1. **Sensitive manometers:** The sensitive manometers are mostly used for the measurement of fan pressure, for determining the pressure difference across separation doors between intake and return, at the pit bottom and at several other places in the mine [3].
2. **Pressure survey meters:** It is a sensible type velometer calibrated to read pressure difference in mm of water-gauge. The pressure survey meters are most suitable for carrying out detail survey of a small mine or part of an extensive mine. Only trained persons can take the readings under strenuous conditions during its use [3].
3. **Sensitive aneroid barometers:** A barometer must be placed above ground near the entrance to the mine and must be read and recorded every day. A record of barometric pressure variations at the pit top at regular intervals of 15 minutes is needed to be maintained during ventilation measurements [3].
4. **Graham's pressure survey apparatus:** The graham's pressure survey apparatus is used in the same way as barometers. But as the pressure measuring element is a gas and not a metal, it voids creep and time lag associated with barometers [3].

5.3 EQUIPMENTS REQUIRED FOR A PRESSURE-QUANTITY SURVEY

1 Rotating vane anemometer

The vast majority of airspeed measurements made manually underground are gained from a rotating vane (windmill type) anemometer. When held in a moving airstream, the air passing through the instrument exerts a force on the angled vanes, causing them to rotate with an angular velocity that is closely proportional to the airspeed. A gearing mechanism and clutch arrangement couple the vanes either to a pointer which rotates against a circular dial calibrated in meters (or feet) or to a digital counter.

The instrument is used in conjunction with a stopwatch and actually indicates the number of "metres of air" that have passed through the anemometer during a given time period. The clutch device is employed to stop and start the pointer or digital counter while the vanes continue to rotate. A zero reset lever is also incorporated into the instrument. Low range vane anemometers will typically have eight vanes, jewelled bearings and give repeatable readings for velocities in the range 0.25 to 15 m/s. High range instruments may have four vanes, low-friction roller or ball bearings and can be capable of measuring air velocities as high as 50 m/s. Digital vane anemometers indicate directly on an odometer counter, an illuminated screen, or feed an electronic signal into a data gathering system. Modern handheld instruments may also be fitted with a microprocessor to memorize readings, dampen out rapid variations in velocity or into which can be entered the cross-sectional area for the calculation of volume flow.

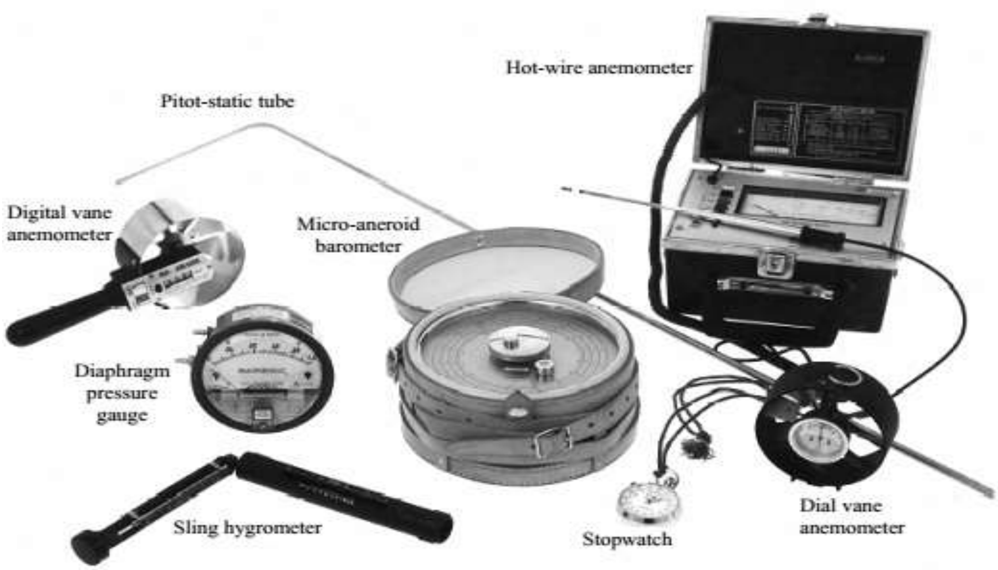


Figure 5.1 Instrument's needed to conduct a ventilation survey [1]

Plate 5.1 Dial-vane anemometer

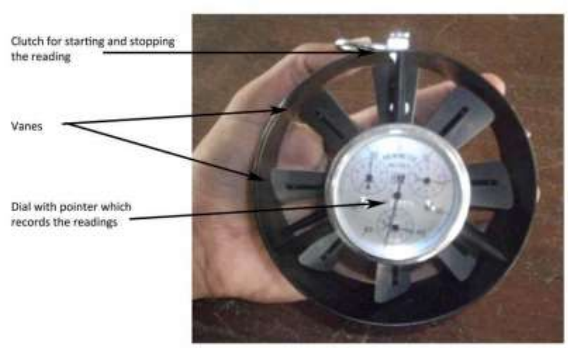


Figure 5.2 Components of a Dial vane Anemometer [22]

2 Inclined Tube Manometer

A variable inclination inclined tube manometer fabricated by DGMS for the purpose of the study at Nandira is used for the differential pressure survey. The inclination of the tube could be set at 1:2, 1:5, and 1:10 depending on the amount of the pressure difference to be measured. The manometer has provision for accurate levelling with the help of three levelling screws when placed on a hard and even surface.

Plate 5.2 Inclined-tube manometer

3 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.

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.

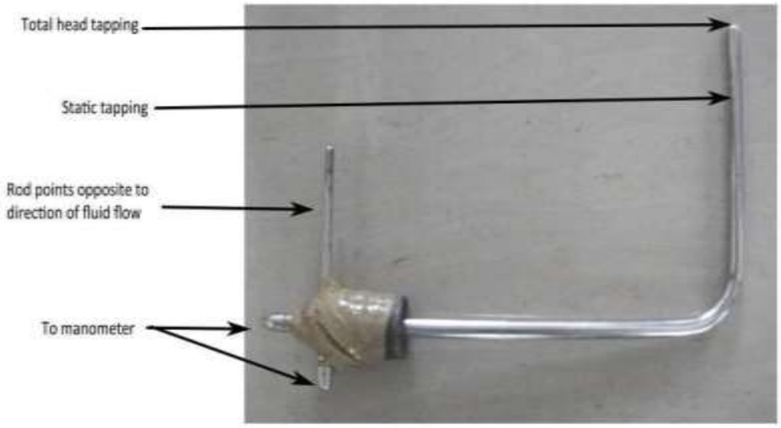


Figure 5.3 Pitot - static tube [22]

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

$$P_v = (P_t - P_s) \ \text{Pa}$$

Where, P_v is velocity pressure in Pascal

P_t is total pressure in Pascal

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 = ρ 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 P_v as

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

Where,

ρ = actual density of air (kg/m^3)

4 Sling Hygrometer

An instrument used to determine the relative humidity of air, the extent to which it saturated with moisture, is known as hygrometer. A hygrometer is convenient to carry underground is Whirling Hygrometer. Two thermometers are placed on a frame and bulb of one is converted with wet cloth. Constant evaporation of moisture takes place from the wet bulb, thereby cooling it and bringing down its temperature. In case of air being relatively dry, it has a low relative humidity and there is large difference between readings of wet bulb and dry bulb. In case of air being nearly saturated, the two readings have hardly any difference. When the frame along with the thermometers is whirled at 200 r.p.m for about a minute which produces a relative air velocity of 3 ms^{-1}, the readings of dry bulb temperature (D.B.T) and wet bulb temperature (W.B.T) are calculated for relative humidity of air.

R.H (%) = 100 – X (D.B.T-W.B.T)

X= 7, for D.B.T > 25

8, for D.B.T, 20-25

9, for D.B.T < 20

An Indian worker may continue to work reasonably well in an underground atmosphere where the W.B.T is 30^0 C or near about. Both temperature and relative humidity of air cause an increase in the vicinity of a place of spontaneous heating of coal and if the hygrometer readings are taken regularly they provide as an indicator whether or not heating is taking place.

Plate 5.3 Sling Psychrometer

5 Nylon Tubes

For measuring the static pressure differential between two station, nylon tubes of 8mm diameter and thickness of 4mm of length 20m was connected with Pitot tube at either end via connectors to prevent leakage.

6 Stop Watch

For the purpose of recording time during air quantity survey for a duration of one minute a stop watch was an essential equipment.

Table 5.1 Instruments for measuring Air velocity in Mines [15]

Instrument	Velocity Range, fpm	Sensitivity, fpm	Accuracy	Features
Smoke Tube	20-120 (low)	5-10	70-90%	Indirect, approximate
Vane anemometer	150-2000 (intermediate to high) 2000-10,000 (very high)	10-25 50-100	80-90%	Needs calibration, needs maintenance
Velometer	30-3000 (low to high) multirange	5-10 25-50	3% of upper scale reading	Rapid, direct reading, delicate, needs maintenance
Thermoanemometer Thermometer	10-500 (low to intermediate)	2-10	80-95%	Slow, delicate, requires power (6V), safe
Hot-wire	10-300 100-3000 (low to high) multirange	1-2 10-20	90-95%	Rapid, direct reading, delicate, requires power, needs maintenance
Kata thermometer	100-1500 (intermediate to high)	10-25	70-90%	Indirect, slow, delicate
Pitot tube	750-10,000 (high)	10-25	90-98%	Slow, indirect, accurate

Conversion factor: 1 fpm= 0.00508 m/s.

5.4 FLOWCHART FOR CONDUCTING VENTILATION SURVEY

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

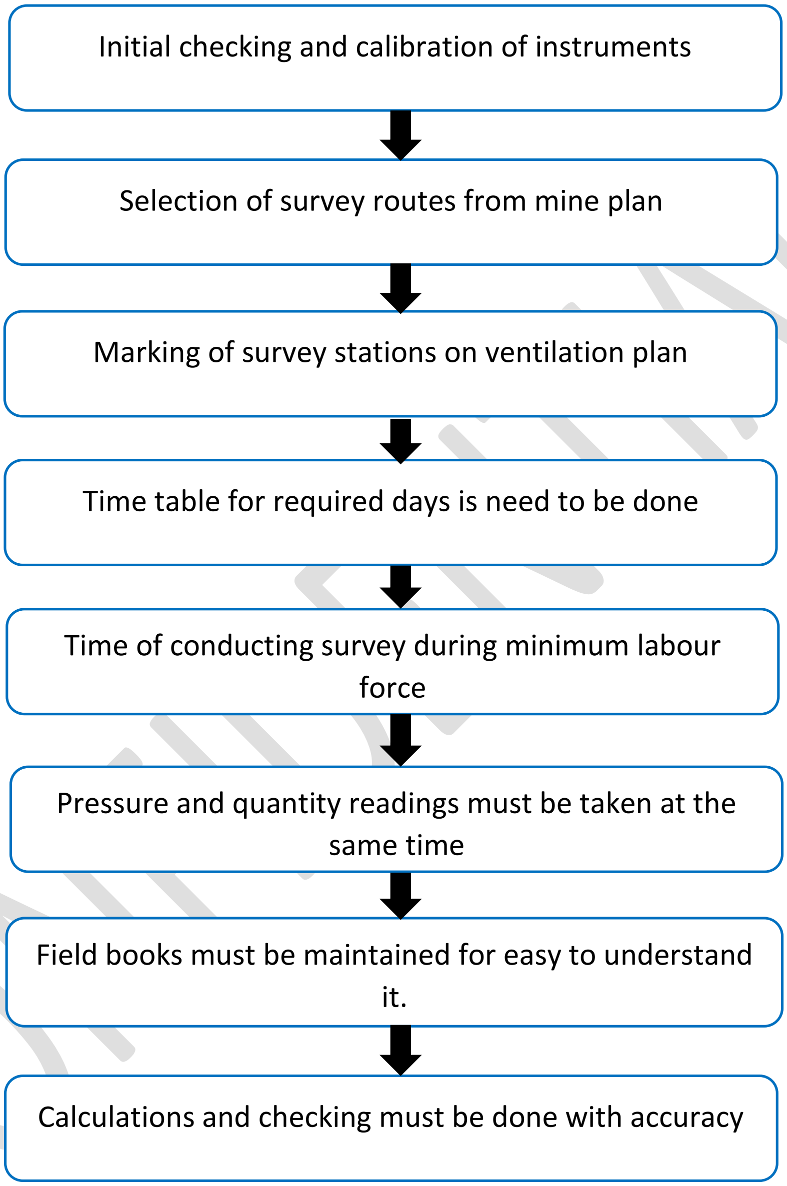


Figure 5.4 Flowchart for conducting ventilation survey

5.5 VENTILATION PLAN [2]

Ventilation plans are necessary for efficient control of ventilation in mines. It is also required by law that up-to-date ventilation plans of a mine showing the distribution of air be maintained as mentioned in regulation no.139, CMR-1957. Ventilation plans are prepared based on the latest ventilation surveys and are essential for:

1) Giving a comprehensive picture of the mine air distribution system with the direction and amount of flow in various branches and circuits.
2) Indicating the position of the high resistance parts of branches and circuits
3) Indicating leakage or recirculation of air
4) Indicating the efficiency of the various ventilation control devices.
5) Indicating possible ways of reorganization of the system for better air distribution.
6) Indicating possible ventilation control measures in the event of emergency and
7) Indicating the effect of introducing new airways, installation of fans etc. in the event of reorganization of ventilation system.

Normally ventilation plans should clearly indicate:

a) The direction of air-current in various branches and circuits.
b) Quantity and pressure measuring stations.
c) Air-crossings, doors, stoppings and other devices for controlling air distribution.
d) Fire doors and stoppings with their serial number.
e) Rooms used for storing inflammable materials.
f) Position of firefighting equipment.
g) Water dams with dimensions
h) Pumping, telephone and ambulance stations and
i) Haulage and travelling roads by suitable symbols. Table below gives the standard symbols prescribed for ventilation plans by the Indian Mine Regulations.

Apart from the above, quantities at the air measuring stations should also be shown on the ventilation plan. Wherever, the scale of the plan permits, airways with unduly high resistance should be specially marked with the pressure drop suitable indicated.

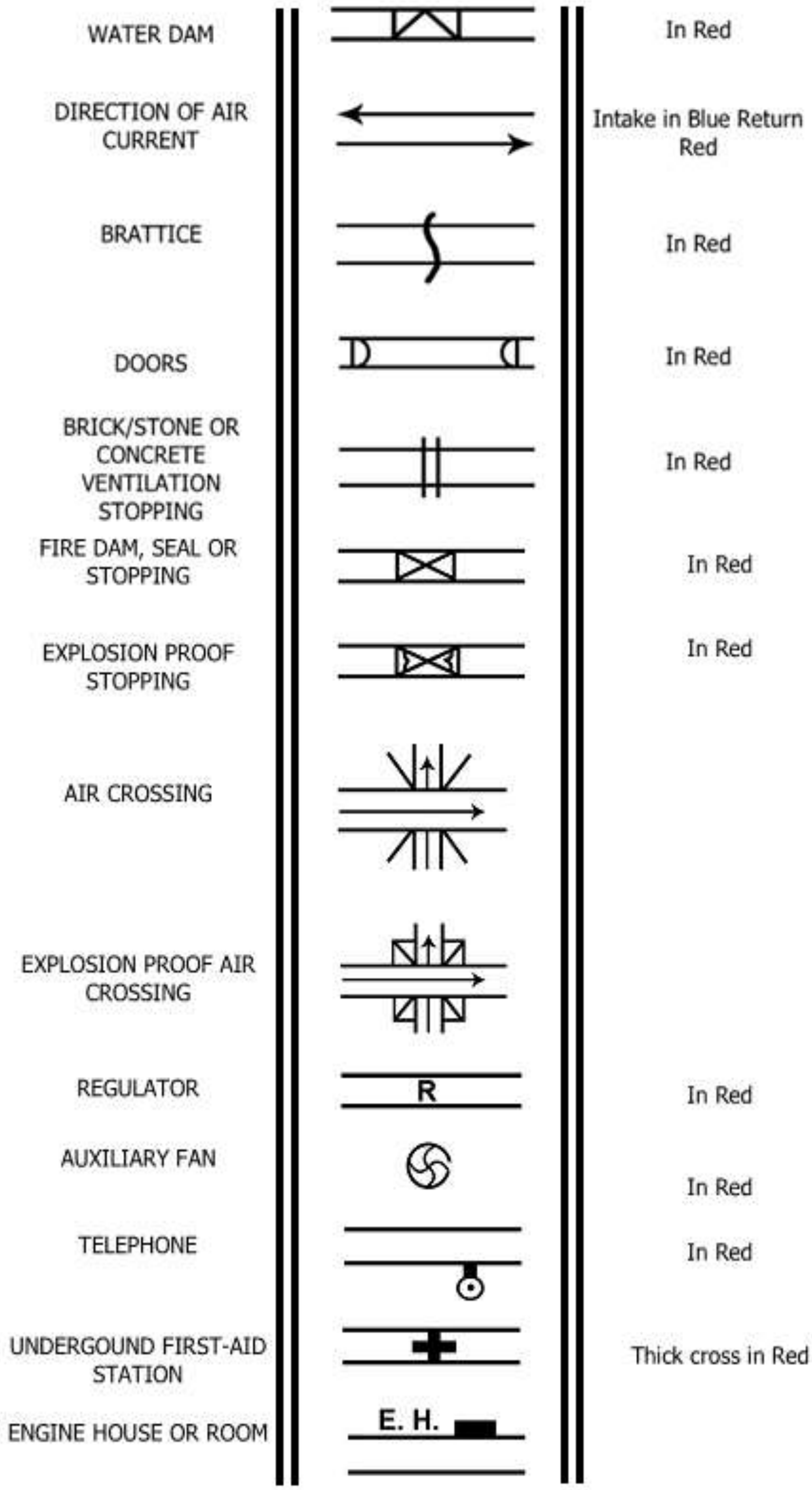


Figure 5.5 Prescribed symbols for ventilation plans

5.6 SELECTION OF MEASUREMENT STATION for PRESSURE QUANTITY SURVEY [22]

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

5.7 PROCEDURE FOR CONDUCTING PRESSURE SURVEY BY GAUGE-TUBE [3]

The procedure for conducting a gauge and tube survey is as follows:

(a) The survey is commenced from the intake air path to return path and moved in the direction of air current.

(b) The inclined manometer is clamped to a tripod stand and levelling was done.

(c) A short connection between the gauge limb and the hose pipe was made by a short rubber tubing. A similar length of light tubing is attached to the open end of the hose pipe and to the other limb of the gauge

(d) The inclined gauge was placed between adjacent stations and the flexible hose was run to extend from station to station.

(e) The ends of the hose are held so that they both face the air current and thus automatically take account of the total pressure, including both the static and the velocity components.

(f) All readings are carefully noted.

(g) The instruments and tubes are then taken forward and the procedure is repeated in all the stations.

5.8 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

5.8.1 Taping [2]

This is the simplest and the most common method of cross sectional area calculation in mines. In this method, a tape is stretched across the airway and with 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 plan meter.

5.8.2 Offset Method [14]

In this method, tapes or strings are stretched across the airway to give a rectangular shape. With the help of another tape perpendicular to the periphery of the airway are taken at frequent intervals of say 0.3 to 0.5 m. the measurements can be plotted on a graph paper from which the cross-sectional area is determined.

5.8.3 Profilometer Method [2]

This method 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 instrument quicker and obviates any personal error in the plotting of the rays.

5.8.4 Craven Sunflower Method [2]

The method 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 thereform.

5.8.5 Photographic Method [14]

In this method, the periphery of the measuring station is marked with a white paint and photographed along with a measuring scale placed in the plane of the cross-section. Very often the whole cross section of the airway is not available for airflow with obstructions created by conveyors, ventilation ducts, pipes, spillage of coal and other equipment. The cross-sectional area of the obstructions should be determined and subtracted from the overall roadway area.

5.9 TRAVERSING METHODS

5.9.1 MOVING TRAVERSES / CONTINUOUS TRAVERSING [2]

This is an approximate but quick method adopted with anemometers in minor airways 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 from side to side as shown in figure below. The distance between adjacent legs of traverses should be about 300 mm for reasonably 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 $3m^2$ whereas 3 minutes may be necessary for an area of $9m^2$. A steady movement of the instrument is desirable for accuracy. A first rate of traversing of the anemometer introduces error in the measured air velocity and to keep down such errors below 2% it is necessary to ensure that the speed of the traversing does not exceed 1/10th of the speed of air being measured.

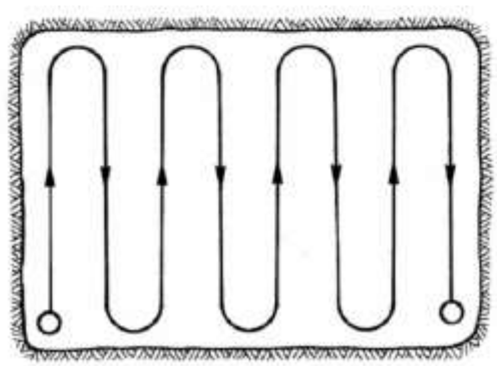


Figure 5.6 Path of a moving anemometer traverse [1]

5.9.2 FIXED POINT TRAVERSES /SINGLE POINT MEASUREMENT [2]

In this method, the measuring instrument (anemometer, velometer or pitot static tube) is held in 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. The method factor varies with the roughness of the sides of the airway and the Reynolds number. However, it can be taken to be constant for turbulent flow with high Reynolds numbers (>50000) as in the case of mine air currents commonly measured with anemometers or pitot static tubes. The method factor is unity at one-seventh of the distance between opposite walls from any wall, or in other words, the average velocity can be obtained directly by placing the instruments at this point. An accuracy of 5 % can be obtained with single point measurement by an anemometer if the airway is straight and of uniform cross section.

5.9.3 METHOD OF EQUAL AREAS / PRECISE TRAVERSING [2]

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 ide 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.

(a) RECTANGULAR[2]

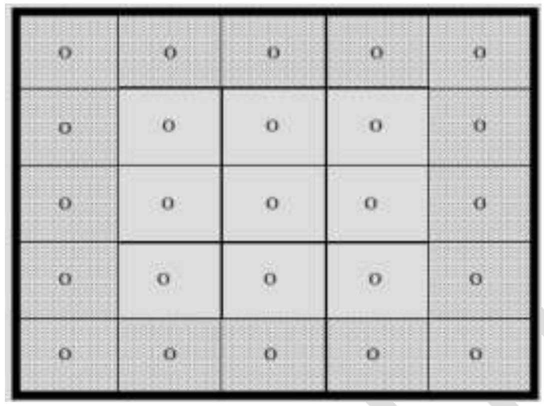


Figure 5.7 Measuring points for a fixed point traverse in a rectangular opening [1]

In this method, the cross section of the airway is divided into equal areas of 300 mm square for ordinary mine airways, the size being less for airways of lesser cross-sectional area as in the case of ducts. Wires are stretched across the airway in such a way that points of their intersection coincides with the centres of these areas where observation has to be made. The instrument is then held at each of these observation points for a suitable length of time, say, a minute or so and the velocity is recorded. The average velocity can then be calculated from these velocities. As a guide, the recommended number of points, n, for a rectangular opening may be estimated as:

$$n=100\ e^{-8/A}+23$$

Where; e is the exponential exponent, 2.7183 and

A is the cross-sectional area (m)

The estimated number of points may then be rounded to a value that is convenient for subdividing the cross-sectional area but should never be less than 24. Correct positioning of the measuring instrument is facilitated by erecting a grid of fine wires in the airway to represent the subsections.

(b) CIRCULAR[2]

For circular airways such as ducts, the measurements are usually done along two diameters at right angles to each other. The measuring points are so located along the diameter (i.e., closer at the periphery and wider apart at the centre) that they represent equal areas.

Table 5.2 Number of measuring points on each diameter of a circular duct [1].

Diameter of duct (m)	<1.25	1.25-2.5	>2.5
No. of points	6	8	12

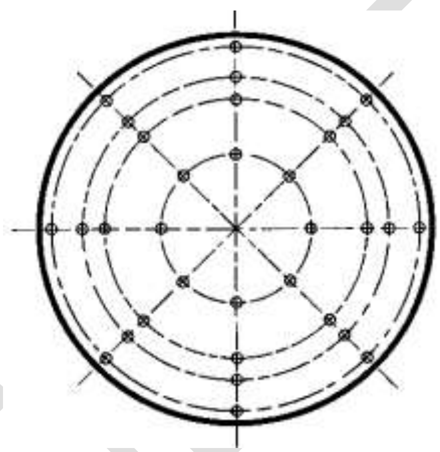


Figure 5.8 Measuring positions for an 8 point traverse on 4 diameters of a circular duct [1].

The locations of the points are at the centre of area of the relevant annulus on each diameter and may be calculated from

$$r = D\sqrt{\frac{2n-1}{4N}}$$

Where,

r = radius of point n from the centre

n = number of the point counted outwards from the centre

D = diameter of the duct (m)

N = number of points across the diameter

5.10 SURVEY RECORDS [2]

Results of ventilation surveys should be suitably recorded and so tabulated as to reveal at a glance the changes in air quantity and pressure. It is also desirable to get the survey results plotted on a ventilation plan of a suitable scale, which should show the air quantities at the various survey stations. An idea of the variation in the resistance of the airways can be obtained by plotting the pressure drop along an airway against the distance. A good way of representing the pressure survey on the ventilation plan is to mark out sections of airways over which a fixed drop of pressure takes place. A short section indicates a high resistance whereas a long one indicates a low resistance. Ventilation measurement data should be recorded at the survey station for ready reference.

In India it is required to post a check board at all air measuring stations in the return in gassy coal mines showing:

a) The serial number of the station.
b) The quantity required to pass through the airway.
c) The cross-sectional area of the airway at the section.
d) The last date of air measurement.
e) Measured air velocity.
f) Measured air quantity.
g) Percentage of inflammable gas in the general body of air and
h) The signature of the ventilation officer with date.

5.11 HYGROMETRIC SURVEYS

Hygrometric survey in mines is normally carried out to check and control the environmental conditions at various parts of the mine so as to maintain the mine atmosphere (wet-bulb temperature and air velocity) within statutorily permissible limits. It is generally carried out by whirling hygrometers, the survey proceeding in a regular manner from the top of the downcast shaft to that of the upcast shaft. Readings must be taken at all splits, points of leakages, haulages, compressors etc., psychrometric readings should be accompanied by measurements of pressure and quantity of air flowing.

Mine air always contains some amount of moisture. There is a maximum quantity of moisture which can be contained in any space of gas, air or even vacuum at a certain temperature. When the air at a particular temperature contains the maximum amount of water vapour it can hold, it is called saturated and can pick up no more water vapour at that temperature. On the other hand if the air can still pick up some more water vapour at the prevailing temperature, it is called unsaturated [2].

5.11.1 Saturated Vapour Pressure [14]

This is the maximum pressure that can be exerted by the water vapour in a saturated atmosphere corresponding to a particular temperature and is expressed in kPa.

5.11.2 Vapour Pressure [2]

This is the partial pressure of water vapour present in a certain volume of air expressed in kPa. This is also sometimes called actual vapour pressure.

5.11.3 Relative Humidity [2]

It is used to represent the moisture content of air. This is the ratio of actual vapour pressure to the saturation vapour pressure at the temperature of observation expressed as a percentage.

5.11.4 Dry Bulb Temperature

Dry Bulb Temperature refers to the ambient air temperature since the temperature indicated in the thermometer is free from any moisture in air. It is also ordinarily referred to be the temperature of air as it is the true thermodynamic temperature.

5.11.5 Wet Bulb Temperature [2]

This is the temperature recorded by a thermometer whose bulb is covered with a thin cotton gauze which is dipped at the lower end into water so that surface of the bulb is kept moist by capillary action. If such a thermometer is placed in unsaturated air, the latter will pick up moisture from the bulb of the thermometer. As a result, its temperature in the vicinity of the bulb will fall owing to the loss of the latent heat of vaporization until the air gets saturated. Once the air gets saturated there will be no further evaporation and cooling of the thermometer when it will show a constant temperature. This temperature is the wet-bulb temperature.

Thus the wet-bulb temperature in conjunction with the dry bulb temperature, gives a measure of the degree of saturation or relative humidity of the air.

5.11.6 Instruments for measuring Relative Humidity of Mine Air [2]

1. Fixed Hygrometer

This is fixed at a suitable place in the mine so as to be well ventilated by the mine air current. It consists of two thermometers mounted side by side, the bulb of one being exposed to the air and that of the other covered with a thin gauze of muslin, the lower end of which is dipped in a container filled with water.

2. Whirling Hygrometer

This consists of a dry and wet bulb thermometer as in a fixed hygrometer and is provided with a handle for whirling it at a rate of 200 r.p.m which produces a relative air velocity of $3ms^{-1}$.

3. Assmann Psychrometer

This is an aspiration Psychrometer with the bulbs of the thermometers ventilated by a fan operated by a clock type spring. The bulb of the thermometers are covered with metal sleeves whose outer surface are bright chromium plated in order to prevent radiation from surrounding surfaces affecting the readings of the thermometers. The fan should be run for three minutes before taking a reading.

5.12 PRECAUTIONS DURING SURVEY

1. Reading should be taken in a uniform cross sectional area.
2. Anemometer must be kept at a distance from body to prevent any obstruction during readings.
3. Anemometer must be kept perpendicular to the directional of air flow during traversing.
4. Sling Psychrometer should be rotated at 200 rpm and not less to get appropriate readings.
5. Calculations need to be done efficiently.
6. Manometer should be handled carefully.

CHAPTER 6
RESULT AND ANALYSIS

6.1 RESULT

6.1.1 FIELD SURVEY

The ventilation survey have been conducted at **Nandira Colliery, Talcher (MCL)** involved the determination of the airflow and differential pressure distribution as well as the quantification of the fan operating pressures. Airflow quantities have been determined by conducting full section vane anemometer traverses and multiplying by a measured cross sectional area. To take the effect of Relative Humidity (R.H) into account, the dry bulb temperature, wet bulb temperatures have also been measured at selected ventilation stations throughout the mine. The mine is affected by sluggish ventilation due to extensive working.

6.1.2 GEOLOGY

Nandira Project is located in the south eastern part of Talcher Coalfields between latitudes 20°53’58” to 20°56’10” and longitude 85°05’40” to 83°08’14”E. Within the leasehold area, the mine has only one seam namely Talcher Seam No.1, lying at a depth of 25m to 110m from the surface. This is the bottom most seam out of total seams occurring in Talcher Coalfields. The seam dips gently in the N45°W direction with a gradient of 1 in 21. The Talcher Seam 1 is in two sections called top (3-5m thick) & bottom (1.5-2.5m).

The leasehold area is surrounded by Balanda OCP on the East, Bharatpur OCP on the North-East, Jambubahali village on the North and Natraj Underground Mine on the West. From the year 1972, mine is producing the coal regularly. Currently the production stands at 0.25 million tones per year, which amounts to about 800 tones per day. Currently the colliery is catering the needs of RSP, Sponge iron Keonjar, NALCO & other ancillary industries.

A portion of the East side panel (EP-IV) has been worked out in top sections, whereas, the West side panels i.e. WP-VG and WP-I&II, where fields studies were conducted, were developed on panel system with pillars of 25mX22.5m size in top section and undergoing depillaring with caving. 13 nos. of major faults varying from 0 to 70m.throw, aquiferrous strata two in the roof & one in the floor of the coal seam.

6.1.3 ACCESS TO THE MINE

The access to the coal seam in Nandira colliery has been affected by two incline drifts (1 and 2) from surface, both used as air-intakes. The incline No.2 is equipped with 800mm. belt conveyor for coal transport. The incline No.1 serves as material transport roadway and is also used for travelling. An air shaft adjacent to the main return serves as the main return.

Table 6.1 Access to Nandira Mine

Name/Type	Gradient (1 in)	Length/Depth (m)	Used as	Intake/Return
Incline 1	3.5	118	Man & Material	Intake
Incline 2	4.5	160	Belt	Intake
Air Shaft	N.A.	32	Ventilation	Return

6.1.4 WORKING DISTRICTS

Development of the mine is almost complete except at very few patches on the western side in Top Section. The Bottom section of the mine has been developed on the eastern side only where the thickness is more than 2m (9 panels). Presently the mine is having 03 depillaring districts (with caving).

Table 6.2 Working districts in Nandira Mine

Name of district	Section	Development / Depillaring	Method of work
WP- I & II	Top	Depillaring with caving	Depillaring with SDLs loading onto belt conveyor, coal winning is by blasting off solid
WP-VG	Top	-do-	
EP-IV	Top	-do-	

6.1.5 SUPPORT SYSTEMS

The RMR of the mine is very poor which varies from 30-40. In the beginning supporting was being done by girders and wooden cross bars. Safari Support for freshly exposed roof was also in practice for quite some time. Junctions and bad roofs were being supported additionally by triangular/square chocks. The above support system failed to cope-up with higher advance of working faces. **Subsequently roof stitching and resin bolting was adopted in 2008 in conjunction with SDL.** The RMR of present districts, support done method of work are mentioned below:

Table 6.3 Support systems at Nandira mine.

Name of district	Section	RMR	Support System
WP- I & II	Top	39	Cement Capsule bolting
WP-VG	Top	39	Resin Bolting
EP-IV	Top	39	Resin Bolting

6.1.6 VENTILATION

The total air quantity available and its distribution in the mine is as follows:-

Total quantity being delivered = 3900 m^3/min.

Table 6.4 Ventilation distribution at Nandira mine

Splits	Prodn. (TPD)	Q.at split begin. m^3/min	No. of Isolation stopping	No. of Vent. Stopping	V.E.Q.	Average Temp.
WP-V(G)	250	1200	Nil	37	80	30^0C
EP-IV	300	940	Nil	18	72	29.5^0C
WP- I & II MD Pump	***	760	20	25	70	28^0C
40L pump	***	400	34	33	66	29^0C
East side	***	600	***	***	***	***

Where,

V.E.Q. is the Ventilation Efficient Quotient of the ventilating district and can be expressed mathematically as,

$$(\text{V.E.Q.}) = \frac{\text{Quantity of air reaching the last connection in a ventilating district}}{\text{Quantity entering the ventilating district i.e.at the start of the split}}$$

6.1.7 MAIN MECHANICAL VENTILATOR SPECIFICATIONS

The mine is being ventilated by one main mechanical ventilator installed on the surface. The fan exhausts air through an air shaft, driven for that purpose. In addition to this faces are ventilated by auxiliary fans.

Table 6.5 Technical specifications of Main Mechanical Ventilator.

Model	PV-200
Type	Axial flow exhaust fan
Make	Voltas
Impeller Dia. (mm)	2000
No. of blades	8
Blade Angle (Degree)	32.5
No. of V-belt grooves	7
No. of V-belts	7
Fan Pulley circumference (mm)	1680
Motor Pulley circumference (mm)	1080
Water gauge (mm)	53
Fan rpm (calculated)	917
Installed motor power(KW) (Twin motor provision in KW, KV.)	105 112, 3.3 & 110, 0.55
Motor RPM	1480
Total Amp. Drawn	16
Voltage (kV)	3.3
Total fan pressure (Pa)	510
Total air quantity (m^3/sec)	69.3

Motor current (amp)	16
Supply voltage (V)	3300
Estimated power factor	0.9
Air power (kW)	35
Motor power input (kW)	82
Overall system efficiency (%)	43

6.1.8 AUXILIARY FAN SPECIFICATIONS

Plate 6.1 Auxiliary Fan

- Diameter : 600 mm
- H.P : 20/550v
- Quantity : 360 m^3/min
- RPM : 2900

6.1.9 INSTRUMENTS USED DURING SURVEY

- Inclined tube manometer.
- Tripod stand.
- Pitot-static tube.
- Dial vane anemometer.
- Stopwatch.
- A measuring tape, copy of ventilation plan, record book.
- Sling hygrometer
- Two sets of long nylon tubes 20 mtr long and two rubber tubing 2 mtr long.

6.1.10 VENTILATION PLAN LAYOUT

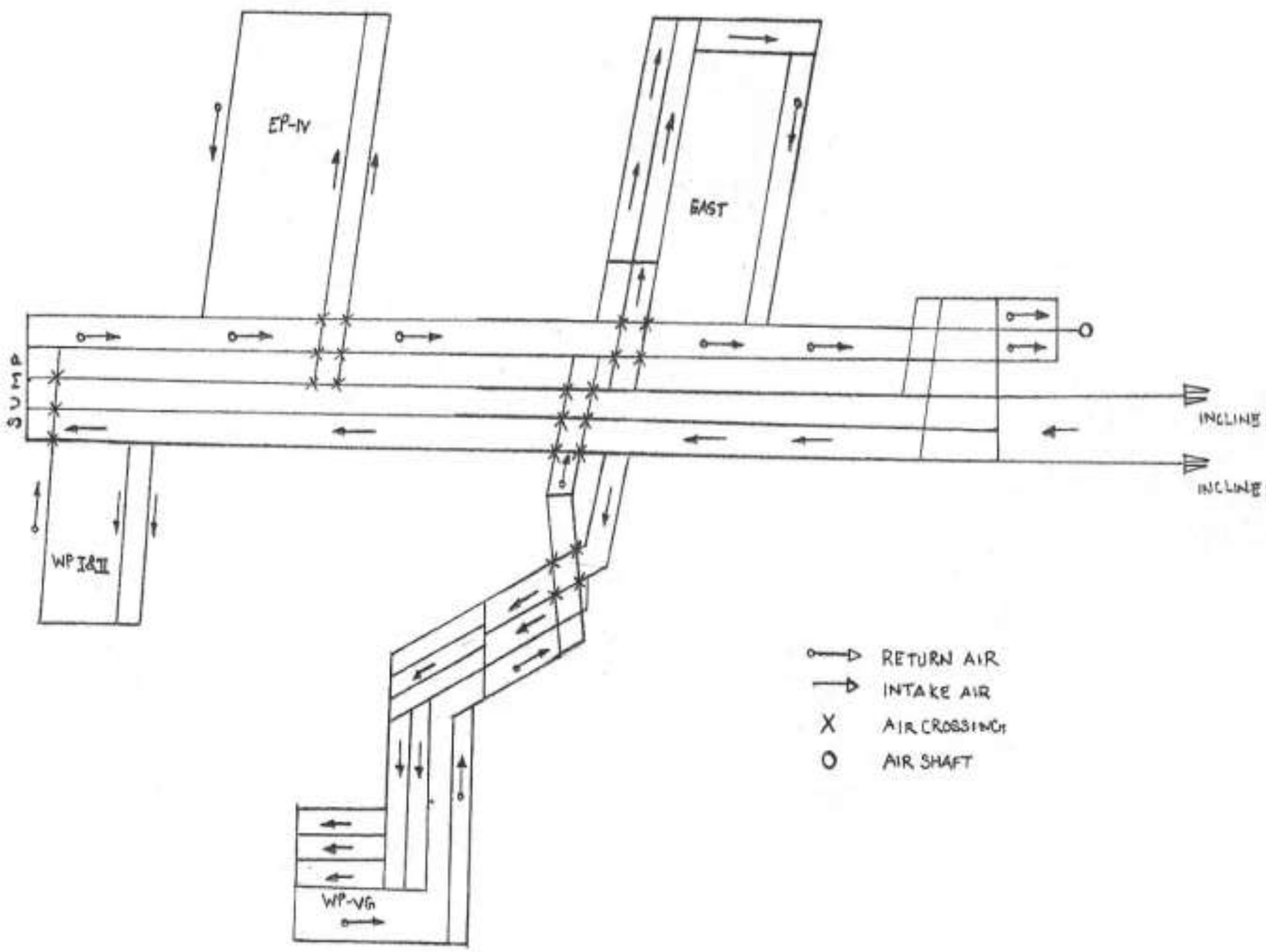


Figure 6.1 Ventilation plan layout

Figure 6.2 Schematic diagram of ventilation systems with nodes.

6.1.11 FIELD SURVEY READINGS

A total of 40 nodes were selected, based on which the measurement was taken.

Table 6.6 Field survey readings

6.2 ANALYSIS

6.2.1 VENTSIM VISUAL- ADVANCED VERSION

Ventsim is an electronic checking and control framework programming, which gives prompt or constant data about every branch in an underground ventilation system. It is developed and distributed by Chasm Consulting based in Australia and marketed in India by Data mine International Ltd. These framework measures the air quantity and pressure changes in the ventilation branches for the input values and simulate the model through all different branches. Ventsim represents an actual ventilation conditions of the existing mine. Without a correct representation of existing conditions, the model could lead to incorrect results for the purpose of planning future design. For which validating the model with accurate data is necessary. Accuracy here means the difference between modelled air quantity pressure data’s and actually measured data’s. Accurate resistances depend s upon accuracy of complete pressure survey. This accuracy may from 90-95% depending upon quality of input data into Ventsim model. Theoretically in a Ventsim model, output simulation will be perfect if input data is perfect. Ventsim uses the Hardy Cross Algorithm for achieving accuracy within the tolerance limit for simulation error. Ventsim uses standard design size and default friction factors and shock losses to design because the above mentioned parameters are always not exactly known. This ensures 85-90% accuracy with pressure surveys for not being able to measure actual resistances [23].

Ventsim likewise permits attributes like heat, gas and other contaminant levels for production purposes. A fitting adjust in air flow and well maintained splits are kept up. An entire model of ventilation framework can be made once the pressure quantity survey readings are entered.

Hardy Cross Algorithm

This algorithm is used to solve complex ventilation networks in which suitable quantities for different branches are assumed giving due consideration to Kirchhoff's first law i.e. law of continuity of flow. The closer the assumed quantities to be true the less is the number of successive iterations.

This algorithm have been developed by Hardy Cross a Professor in the University of Illinois, had developed the technique in1936 for application in water distribution systems [24].

Advantages of using Ventsim are:-

(a) Determine the effectiveness of ventilation design of the underground mine by proper monitoring.
(b) In case of incorrect entries or improper data details, it indicates the airway number along with the type of problem existed.
(c) Helps in monitoring of leakage in the goaf side due to sudden change of air quantity.
(d) Detects any sort of blockage in the airway.
(e) Performance of fan can be monitored on real time data's and suggests in providing an optimal solution to the fan installation or changes.
(f) Gives a successful way out course bearing if there should arise an occurrence of crisis for underground faculty and rescue group for departure.
(g) Save time lost in measurement and checking of underground ventilation by mine officials.
(h) Detects failure of regulators and sudden changes in differential pressure.
(i) Detects in failure of stopping to prevent any potential spontaneous combustion.

6.2.2 SIMULATION RESULTS AND SURVEY DATA'S COMPARISON

Table 6.7 Estimation of leakages

6.2.3 VENTSIM MODELLING

Figure 6.3 (i) Ventsim model design of the ventilation network of the coal mine

Figure 6.3 (ii) Simulated model design of the ventilation network of Nandira coal mine

6.2.4 FAN CHARACTERISTICS

Figure 6.4 Characteristics curve of MMV

The mean efficiency from the above fan characteristic was found to be 42.85 %.

Figure 6.5 Fan characteristic curve and operating point

The operating point is the point of intersection of the mine characteristic curve, and the static pressure curve of the ventilation fan. The operating point indicates the pressure and volume for which the fan would be mechanically suited. The operating point in figure 6.5 results in low mine quality at 62 m^3/s. The power input to the fan gets dissipated in the wasteful form of the K.E, resulting in unnecessary energy costs and thus is uneconomical. While the operating point from Ventsim is found to be around 72 m^3/s.

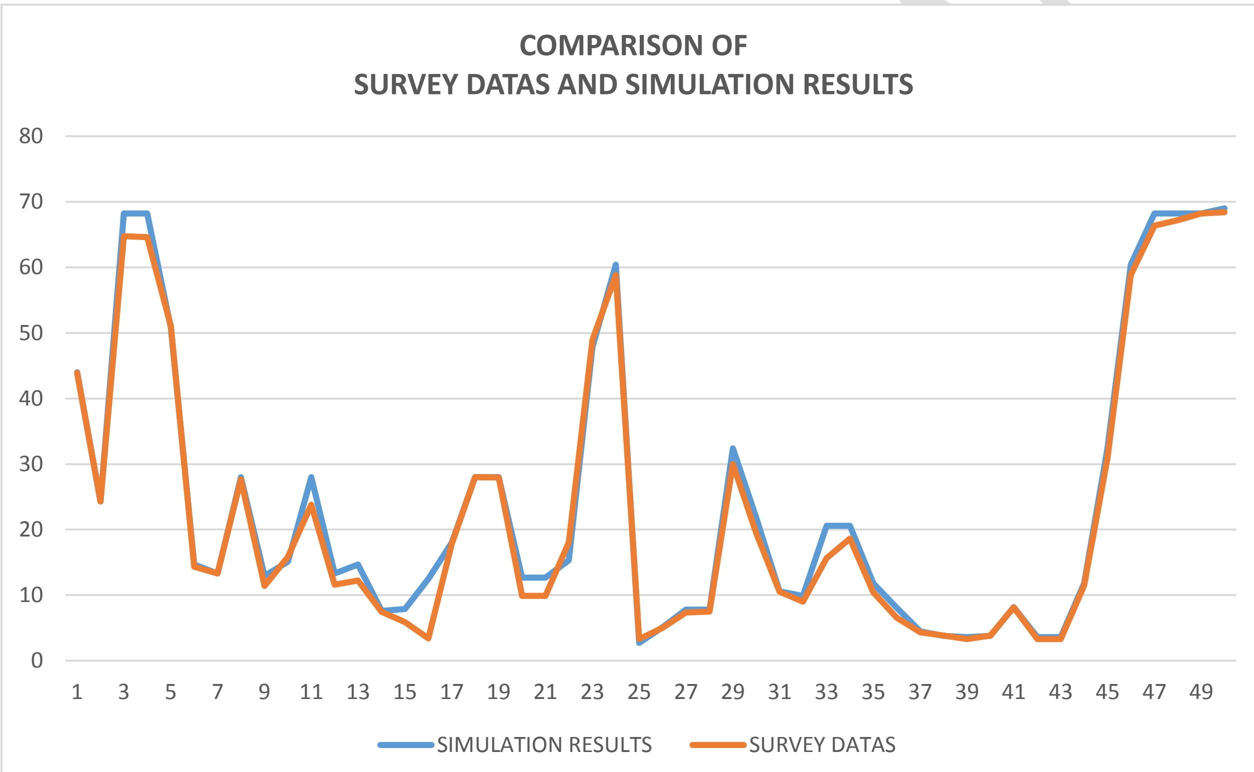


Figure 6.6 Comparison of field studies and Ventsim results.

The comparison of the field survey values and Ventsim simulation results is shown in figure 6.6 illustrating the closeness of the values estimated in two tests. A little differences were observed at reading 3-5, 11, 15-17, 19-21, 33-35 and 45-47.

From the correlation graph shown in figure 6.7 below, analysis between field results and Ventsim simulation shows a positive correlation as 0.9895.

Figure 6.7 Correlation analysis of field studies and Ventsim results.

6.2.5 OBSERVATIONS

The air velocity in branch node have been compared in both the field survey readings and simulation results. The air velocity found in field readings are comparatively lower than simulation results due to high resistances and obstructions in the mine.

Table 6.8 Velocity analysis in branch nodes.

CHAPTER 7
CONCLUSIONS

7.1 CONCLUSIONS

From the results obtained, correlation analysis, comparison of the field data and simulation values the followings points are observed.

- Maximum leakage is observed to be 4.94 m^3/sec at the nodes 28-29 in EP-IV panel near the goaf area and zero leakage is observed at nodes 2-3, 5'-6', 15-16 and 39-40.
- The field readings and simulation results have a positive correlation of 0.9895.
- The Relative Humidity (R.H) is maximum of 95.1 % at node 25-38.The Relative Humidity (R.H) is minimum of 78.4 % at node 7-8.
- Least velocity of air in field survey is observed at node 31-32 with a velocity of 0.21 ms^{-1} and maximum velocity at node 3-4 (intake air) with a velocity of 12.95 ms^{-1}.
- Least velocity of air in Ventsim simulation is also observed at node 31-32 with a velocity of 0.21 ms^{-1} and maximum velocity at node 3-4 (intake air) with a velocity of 13.64 ms^{-1}.
- Differential Pressure is observed least to be at nodes 11/2-13, 29-30 and 35-30 with a value of 0.2 Pa and maximum to be at nodes 5-23 and 5'-22 with a value of 151 Pa and 103.5 Pa. Also at node 39-40 beyond MMV with a value of 319 Pa.
- Simulation results and Field readings differs overall with an average of 13.145 % as a result of resistances faced during field survey due to movement of tubs, leakages, working hours of the personnel , instrumental errors and faulty Air Measuring Stations.

It is also observed that at nodes 31'-33 and 31-32 (working faces) of district WP I & II the velocity of air is flowing at 0.32 and 0.31 ms^{-1} which is below the DGMS recommended level for air velocity of 0.5 ms^{-1} (Table 3.4). This problem can be solved by-

- Installation of an additional air shaft or booster fan will gradually increase the air flow in the places.
- An effective construction of ventilation stoppings at intake air-route will ensure minimal loss of fresh air at the stoppings.

- Use of regulator at crossover will ensure effective distribution of air quantity and minimize losses.
- Enlarge the cross sectional areas of the roadways and make them smooth lined.
- Speed up the surface fan.

7.2 RECOMMENDATIONS

Based on the existing ventilation problems at Nandira mine, the following recommendations were suggested

- Calibration of pressure measuring instrument at regular interval is required for accurate periodic survey.
- Removing the blockage if not necessary at the return airways.
- Air should be properly coursed up to faces with the help of auxiliary ventilators.
- The existing PV-200 fan is to be replaced by a fan of 100m^3/sec of air quantity.
- Air should be properly coursed up to LVC (Last Ventilation Connection) of the district by strengthening the stoppings and doors (minimize the leakages).
- In the district, air from LVC should be coursed up to the faces by auxiliary ventilators.
- Leakage roots are large in numbers causing a decrease in volumetric efficiency which can be solved by increasing the pressure and minimize the leakages.
- Maintenance of Air Measuring Stations at regular intervals.

REFERENCES

1. McPherson, M.J. (1983), Subsurface Ventilation and Environmental Engineering, Netherlands: Kluwer Academic Publishers, pg.4.2-4.15, 6.1-6.20.
2. Misra, G.B. (2002), Mine Environment and Ventilation, New Delhi: Oxford University Press, pg. 454- 562.
3. Ghatak, S. (1993), Mine Ventilation, Coal Field Publishers, West Bengal, India, Vol. II, pg.126-135, 195-220.
4. Vutukuri V.S. and Lama R.D. (1986), Environmental Engineering in Mines. Cambridge, Cambridge University Press, pg. 314-315.
5. Ray S.K., Sahay N., Singh R.P., Singh A K and Bhowmick B.C. (2002), Reversal of underground mine ventilation, Journal of Mines, Metals & Fuels, 50 (9), pg. 339-344.
6. Sahay N., Ray S.K., Ahmad I., Varma N. K., Singh R. P. and Singh A. K. (2003), Improvement in Ventilation in a fire affected mine, Journal of the South African Institute of Mining and Metallurgy, 103. pg. 465-476.
7. Sahay N. ,Varma N. K., Ahmad I., Singh A. K., Ray S.K. and Singh, R. P. (2002), Chamber method of ventilation - a proven technology for reducing leakage of air into the goaf, Journal of Mines, Metals & Fuels, 50 (9), pg. 345-350.
8. Varma N. K., Sahay N., Ahmad I. and Sinha, A. (2009), Significance of ventilation system design on fire with special reference to extensive and fire affected mine, Journal of Mines, Metals & Fuels, 57 (11), pg. 413-417.
9. Rowland, J A. (2010), Survey Execution to Build a Ventilation Model, Australian Style, in 13th United States/North American Mine Ventilation Symposium, Hardcastle and McKinnon (Eds.) Sudbury, Canada, June 2010.
10. Rowland, J A. (2011), Ventilation Surveys and Modelling - Execution and Suggested Outputs, 11th Underground Coal Operators' Conference, University of Wollongong & the Australasian Institute of Mining and Metallurgy, pg. 214-224.
11. Rowland, J A. (2009), Moving the Ventilation Report into the 21st Century, in Proceedings of 9th Coal Operators' Conference (Eds: N Aziz and J Nemcik). University of Wollongong and the Australasian Institute of Mining and Metallurgy, 2009, pg.155-174.

12. Prasad, S.D. and Rakesh (1992), Legislation in Indian Mines-A Critical Appraisal, Vol.-II, pg.1126-1127.
13. Deshmukh, D. J. (2008), Elements of Mining Technology, Vol. – II, Denett & Co., Nagpur, India, pg. 3.23-3.26.
14. Banerjee S.P. (2003), Mine Ventilation, Lovely Prakashan, Dhanbad, India, pg. 318-332
15. Hartman H.L., Mutmansky J.M. and Wang Y.J. (1982), Mine Ventilation and Air Conditioning, John Wiley & Sons, New York, pg. 186.
16. Kaku, L.C. (2013), Coal Mining Regulation-1957, Lovely Prakashan, pg. 194-201.
17. Akande J.M, Onifade M. and Aladejare EA. (2013), Determination of Airflow Distributions in Okaba Underground Coal Mine, Journal of Mining World Express, USA, Vol. 2, Issue 2, pg. 40 – 44.
18. Morla R., Tanguturi K. and Rao, A.M. (2012), Selection of optimum combination of fans for bord and pillar coal mines, 12th Coal Operators' Conference, University of Wollongong & the Australasian Institute of Mining and Metallurgy, pg.221-228.
19. Calizaya, F., Stephens, M., and Gillies, S. (2010), Utilization of booster fans in underground coal mines, SME Preprint No. 10-095. Littleton, CO: SME. Annual Meeting February 28-March 3, Phoenix, AZ, pg. 1.
20. Prosser B.S., and Loomis I.M. (2004), Measurement of frictional pressure differentials during a ventilation survey, Proceedings of the 10th US Mine Ventilation Symposium, University of Alaska, Anchorage, pg. 59-66.
21. Kaku, L.C. (1994), DGMS Circulars, Lovely Prakashan, pg.368-369.
22. http://nptel.ac.in
23. http://www.ventsim.com/training-support/tutorials/tutorial-validating-your-ventsim-model.
24. Cross H. (1936), Analysis of Flow in Networks of Conduits or Conductors, Bull, Illinois University. Eng. Exp. Stn. No, 286.

****