MINE ENVIRONMENTAL ENGINEERING AND RESCUE

Soumya Ranjan Mallick

LECTURE NOTES

DEPARTMENT OF MINING ENGINEERING
GCE, KEONJHAR

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CONTENT

MINE GASES

Noxious and poisonous gases found in mines.

1. **Blackdamp**-Carbon dioxide (CO_2) +Nitrogen (N_2)

Also called **Chokedamp** or **Stythe**

2. **Firedamp**-Methane (CH_4)

3. **Whitedamp**-Carbon monoxide (**CO**)

4. **Stinkdamp**-Hydrogen sulphide (H_2S)

5. **Afterdamp**-Carbon monoxide (**CO**) + Carbon dioxide (CO_2) + Nitrogen (N_2) + Hydrogen sulphide (H_2S) + Sulphur dioxide (SO_2) + Oxygen (O_2)

Common gases in mines-O_2, N_2, CO_2, CO, H_2S, SO_2, H_2, CH_4, Nitrous fumes

Oxygen (O_2)

O_2 is a vital element in atmospheric air which human beings and animals breathe for their existence.

O_2 is ***colourless***, ***odourless***, ***tasteless***, slightly soluble in water, slightly heavier than air (Specific gravity 1.1)

Oxygen of air in a mine is consumed for

1. Breathing by persons

2. Slow oxidation of coal and carbonaceous materials

3. Burning of flame safety lamp, acetylene, lamps, naked lights

4. Decay of timber by fungus growth

Mining laws in India require that mine air should contain ***19%*** O_2.

Minimum limit is ***20%*** in USSR

Minimum limit is ***19.5%*** USA

Carbon monoxide (CO)

1. **CO** is produced when carbon or carbonaceous matter is burnt with insufficient supply of oxygen.

2. Gas is ***colourless***, ***odourless***, ***tasteless*** and ***non irritating***. It is slightly lighter than air (Specific gravity 0.967) and combustible, but does not support combustion.

Reasons of Production

1. Oxidation of coal and other carbonaceous matter

2. Explosives

3. Spontaneous combustion

4. Methane or coal dust explosion

5. Underground Machine-Exhaust gas of internal combustion engine like diesel locomotives, air compressor etc.

Physiological Effects of CO

Symptoms of CO poisoning-headache, loss of strength, paralysis (in some case)

Table 1: Physiological Effects of CO

Concentration	Physiological Effects
0.02	headache, discomfort, possibility of collapse after 45 minutes at work or 2 hours at rest
0.12	palpitations after10 minutes at work 30 minutes at rest
0.2	unconsciousness after 10 minutes at work or 30 minutes at rest
0.5-1.0	Death after 10-15 minutes of work

Detection of Carbon monoxide

Warm blooded birds like *Munia* or *Mouse* are commonly used as they are affected much earlier than man.

Only fresh birds are used as some may get accustomed to small percentage of gas.

Carbon dioxide (CO_2)

1. CO_2 is ***colourless***, ***odourless***, bitter in taste with specific gravity 1.52

2. It is soluble in water

3. It is not combustible and does not combustion

4. It is present in return air of all mines in very small percentage

5. It is found in dip areas of depillaring districts of coal mines

6. It is produced from breathing, burning of flame lamps, decay of timber, slow oxidation of coal in mines, blasting, working of internal combustion engines such as diesel locomotives, gas outburst in coal mines.

Table 2: Physiological Effects of CO_2

Concentration	Physiological effects
3%	breathing doubled at rest
6%	violent panting, headache, exhaustion
10%	severe distress after ½-1 hour of work, suffocation, unconsciousness
15%	consciousness loss
25%	death after hours

CO_2 has an extinguishing effect on flame safety lamp. Flame becomes dim at low concentration and will extinguish if held for long.

Methane (CH_4) - Firedamp

1. Methane (CH_4) - Firedamp- It is a mixture of gases emanating from strata of a coal mine. Other gases found in firedamp are ethane and ethylene etc.

2. It is responsible for gas explosions in coal mine

3. It is tasteless, odourless, and lighter than air (Specific Gravity-0.553)

4. It is combustible, burns with a pale blue flame but does not support combustion

5. It is not poisonous but suffocates a person due to lack of oxygen if present in large quantity.

6. It is a product of decaying of cellulose ($C_6H_{10}O_5$) and is formed whenever vegetable matter decomposes under water and out of contact with air as in marshes. So it is also called ***marsh gas***.

7. It forms part of coal seam and is associated strata as coal has been formed million years ago.

8. It remains in coal partly in state of mechanical imprisonment in small ***cavities***, ***breaks***, ***fissures***

9. It moves prevalent in deep mines.

10. It is also found in ***rock salt***, ***potash*** and ***clay mines***.

11. It is found in a mica mine (DGMS circular No.18, 1961) - 3 workmen were seriously injured.

Firedamp/ marsh gas can be formed by decomposition of ***timber*** (or) ***vegetable matter***.

1. Found in form of gas outburst associated with violence
2. In form of a blower. Can be felt in hand and can be heard.
3. Release by roof fall or sudden fall of barometric pressure.
4. As gas is lighter than air found near roof and in rise working.
5. In a badly ventilated road way, it found throughout roadway due to diffusion of gas in air.
6. Fault plane, dykes-Gas may be expected in non gassy coal mine.

Factor affecting gas emission

1. Nature of coal seam and adjacent strata
2. Method of mining and type of coal cutting machine used
3. Ventilation arrangement and their efficiency

4. Speed of advance of longwall face (or) general production face in board and pillar method

NB- Rate of emission is more during coal cutting shift on a longwall face

Table 3: Degree of gassiness of a coal mine (DGMS circular 1967)

Gassiness (Degree)	% of inflammable gas in general body of air	Rate of emission of gas (m^3/te) of coal raised
I	<0.1	<1
II	>0.1	1-10
II		>10

Sulphur dioxide (SO_2)

1. It is Colourless with strong sulphurous smell
2. It is neither combustible, nor support combustion
3. It is 2.21 times heavier than air
4. It is very poisonous, extremely irritating to eyes and respiratory passages
5. It is produced in small quantities during blasting, after fire or coal dust explosion.

Nitrous Fumes

1. It is Mixture of different oxides of nitrogen NO, NO_2, N_2O_3
2. Choking smell
3. It is yellow-reddish brown in colour
4. It is easily dissolved by mixture in mine air
5. It is formed during blasting of explosives containing nitroglycerine
6. Exposure for a few minutes causes headache

Hydrogen sulphide (H_2S)-Stinkdamp

When coal containing sulphur is heated out of contact with air at temperature 444^{0}C

Coal may contain sulphur in very small quantities in form of pyrites or finely disseminated organic compounds of sulphur.

1. It is colourless and has smell of rotten egg
2. It is combustible, but does not support combustion
3. It forms explosive mixture, when mixed with air
4. It burns in air with pale blue flame
5. It occurs ordinarily in traces in few coal and metal mines
6. It may be found in stagnant water in old workings, in areas of gob fires or spontaneous heating
7. In metal mines it may be produced by action of acidic waters on sulphide ores
8. It is as poisonous as CO. It may cause death in a short time if inhaled in large quantities
9. Maximum permissible concentration in rooms for 8hrs exposure is 0.02%
10. A blotting paper soaked in lead acetate changes its colour to black in presence of H_2S
11. A moist silver coin change its colour to black due to formation of black sulphide on surface
12. It can be detected by Drager Multigas Detector and MSA hydrogen sulphide detector
13. H_2S detector tube contains white granules of activated aluminium oxide coated with silver cyanide which turns greyish black if exposed to H_2S.
14. CMRS has patented a H_2S detector tube which detects 1-50 ppm of H_2S.

Blackdamp

1. It is a mixture of CO_2 and N_2 in higher percentage than normal percentage in mine air.

CO_2 –negligible to 20%

N_2-80%-100%

The composition mainly depends upon manner of formation of CO_2 in mine.

If CO_2 is formed by ***oxidation of coal***, then composition is ***CO_2-5%*** and ***N_2-95%***

If CO_2 is formed by ***rotting of timber***, then the composition is ***CO_2-20%*** and ***N_2-80%***

2. It is colourless, odourless and may be acidic taste due to presence of CO_2

3. It does not support combustion and is not poisonous

4. Effects of breathing blackdamp depend on its composition

Table 4: Physiological effects of blackdamp (12% CO_2 and 88% N_2)

Concentration	Physiological effects
25%	Breathing rate doubled
40%	More frequent and deeper breathing
50%	Panting, headache and face turns blue

1. Heavier blackdamp gives a warning a warning of CO_2 presence, but lighter blackdamp does not give warning, so more dangerous

2. A victim of blackdamp recovers rapidly on breathing fresh air or artificial respiration

3. Blackdamp affects flame of an oil flame safety lamp. For every 5% blackdamp (corresponding to 1% reduction in O_2 percentage) light diminishes by 30% and extinguishes when O_2 percentage falls below 17.5%.
4. Blackdamp can be partially cleared away by sprinkling lime. Large concentration can only be removed by improved ventilation.

Sequential Air sampler (After Anon, 1977)

1. To overcome disadvantages of spot sampling, USBM has developed a mechanical driven sequential sampler that can take air samples for 1-8 days.
2. The sampler consists of a spiral of plastic tubing wound around a cylinder, which is tilted so that one end of tube is submerged in a pan of water.
3. The other end of cylinder is connected to a spring wound motor which rotates the cylinder at set of intervals of once a minute to once an hour.
4. A sample is taken every revolution.
5. As cylinder rotates, the low end of tubing comes out of water for a half a revolution of cylinder.
6. As the end of tube submerges again, a plug of air is trapped in the tube between two plugs of water and successive air samples are automatically spiralled upward in the tubing as cylinder rotates.
7. Clamps are used to prevent samples from mixing when tubing is taken from mine to laboratory analysis.
8. A syringe is used to draw sample from the plastic tube.
9. Sample should be analysed as quick as possible as some gases may be lost by diffusion from plastic tubing.

Instruments for detection and monitoring of gas

Thermal conductivity instrument-

1. An electrically heated wire immersed in sample cools at a rate different from its cooling rate in the reference gas.
2. This principle is used for measuring gas concentration by forming a ***Wheatstone bridge circuit*** in which two physical similar wires serve as detector element.
3. One immersed in sample to be tested and other in reference gas.
4. With reference gas element resistance held constant, change of resistance of element in the sample unbalances the bridge in proportion to concentration of gas present in sample.
5. Hand held detectors are available for CH_4

Coward diagram

1. Figure shows whether methane- air mixture is explosive, (or) would become explosive on addition of more methane or more oxygen.
2. When O_2 is less than 12%, any (%) of CH_4 is not explosive.
3. Higher limit of explosibility gradually decreases from 14.8%-6% with decrease of O_2 (%)
4. Lower limit of explosibility increases only slightly from 5.4%-6% for all % of O_2 down to about 12.1%.
5. The diagram is used when sealing off an area on fire or when reopening a sealed off area.

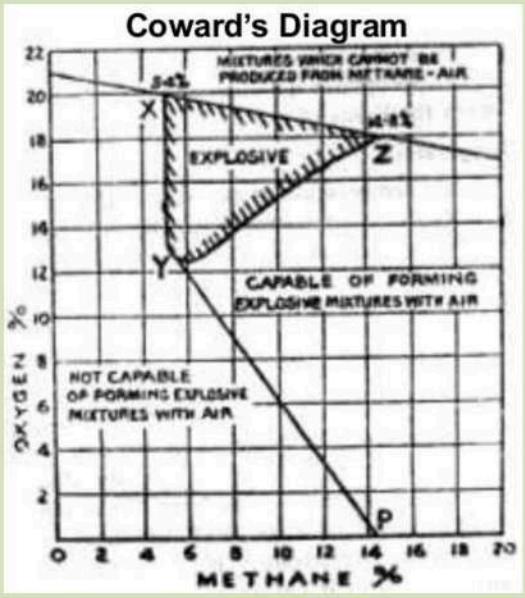

Figure 1: Coward's diagram

Methanometer

1. Battery operated land held portable instrument suitable for making spot checks of methane concentration at any place underground.
2. D-6 methanometer made by MSA, weighting about 470g and capable of measuring 0-5% (CH_4) is a popular instrument approved by DGMS.
3. It carries a nickel-cadmium cell which is charged when voltage goes down after about 500 tests.
4. When a mixture of methane-air is drawn in to the instrument, it comes in contact with a catalytic element.
5. A rapid combustion of gas takes place which raises temperature and resistance of 1 kg of wheatstone bridge, throwing the bridge, throwing the bridge out of electrical balance.
6. The imbalance is indicted by needle as % of CH_4.
7. For measurement of CH_4 (%) at any place, the inlet cap is opened, by pressing methane-check button. Methanometer is taken to that place. The needle shows gas (%) instantly.

8. It is provided with a telescopic probe for detection of gas in inaccessible places (***roof cavities***, ***high places***).

9. The instrument is sent to CIMFR, Dhanbad every 3 months for re-calibration.

10. By Convention, methanometer means a portable hand-held battery operated apparatus, Bulkier instrument for measuring CH_4 are called Automatic Firedamp detectors, Methane Monitors etc.

Testing of firedamp

Indian law does not permit methane concentration to exceed 0.75% in return of ventilating district or 1.25% in any part of mine.

No shot is allowed to be charged, stemmed or fired at a place where inflammable gas is detected or at any place on its return

It is also required that electric power be cut off from a district where percentage of inflammable gas exceeds 1.25%

Where electricity is used in gassy mines, percentage of inflammable gas is required to be determined on intake side of 1st working face and on return of last working face of a district every 30 days so long as concentration does not exceed 0.6% beyond which weekly determinations become essential.

If however percentage exceeds 0.8% such determinations have to be done daily

For this reason it is essential to detect presence of firedamp and ascertain its quality at various working places in a mine.

Accumulation Test & Percentage Test

Where there is possibility of high concentration of CH_4, first accumulation test is done and then percentage test.

Oxymeter/Toximeter

1. PAC-III is a portable hand held gas detector (weighting only 185 g) manufactured by Draeger company measuring CO,O_2, H_2S concentrations.
2. It has several electrochemical cells for particular gas.
3. It has adjustable audio-visual alarm.
4. It operates with nickel-cadmium battery.
5. Illuminated display can be seen in dark.
6. Range of sensor-CO-0-2000 rpm

   O_2-0-25%

Multi Gas detector

1. Commonly used in Indian mines are manufactured by ***MSA***, ***Auer*** and ***Draeger*** company.
2. Drager Multigas Detector is used to measure CO, CO_2, H_2S, SO_2 and NO_2 [But not CH_4, O_2 due to inaccuracy]

Question 1: Analysis of a sample of air from old workings is reported as follows:

3. O_2= 16.52%; CO_2=3.1%; CH_4=2.45%; N_2=77.93%

Find % of air and blackdamp in sample as well as composition of blackdamp

Answer- Taking air to contain O_2=20.95%, CO_2=0.03%, N_2=79.02%

(16.52/20.95) × 100 = 78.85% air

(16.52/20.95) × 79.02 = 62.31% N_2 in air

(16.52/20.95) × 0.03 = 0.02% CO_2

Excess (N_2) = (77.93-62.31) = 15.62%
Excess (CO_2) = (3.1-0.02) = 3.08%
Blackdamp = (15.62 + 3.08) = 18.70%
Composition of blackdamp N_2 = (15.62/18.70) × 100 = 83.53%
CO_2 = (3.08/18.70) × 100 = 16.47%

Question 2: Samples of air collected in intake and return gates of an advancing longwall face show 0.2 and 0.7% CH_4 respectively. Calculate methane emission per tonne of coal mined, if production from face averages 1000t per day and an air quantity of 20m^3/s circulates along face.

Answer-Quantity of CH_4 picked up by air = 20(0.7-0.2)/ 100 = 0.1 m^3/s
= 8640 m^3 per day

Emission of CH_4 per tonne of coal = 8640/1000 = 8.64 m^3

MCQ

1. _____ may be found anywhere but is most likely to be encountered in virgin coal, roof cavities, high places, abandoned workings, and places that are improperly ventilated.
   a) Carbon Dioxide
   b) Sulfur Dioxide
   c) Methane
   d) Hydrogen Sulfide

2. Coal dust in the air will decrease the lower explosive limit of Methane.
   a) True
   b) False

3. There can be no explosion when the percentage of Methane is greater than fifteen percent (15%) because the amount of Oxygen present is insufficient for rapid combustion to occur.
   a) True
   b) False

4. For a mixture of strictly methane and air, an explosion is impossible if the oxygen content is:
   a) 19.5 percent or less
   b) 16 percent or less
   c) 12 percent or less
   d) 20.5 percent or less

5. What is the weight of one cubic foot of Methane at 60^0F and 30.00 inches of mercury pressure?

    a) Fifty-three ten thousandths (0.0053) of one pound
    b) Four hundred twenty-four ten thousandths of one pound (0.0424)
    c) Seven hundred forty ten thousandths of one pound (0.0740)
    d) Twelve hundred seventeen ten-thousandths of one pound (0.1217)

6. What percent of Carbon Monoxide can cause death in less than one hour?
    a) 0.1 percent or more
    b) 0.2 percent or more
    c) 0.4 percent or more
    d) None of the above

7. 0.01% of Carbon Monoxide might produce symptoms of poisoning if breathed indefinitely?
    a) True
    b) False

8. What percentage of blood saturation by Carbon Monoxide (CO) will cause death?
    a) 20% - 30%
    b) 25% - 30%
    c) 70% - 80%
    d) 40% - 50%

9. This dangerous gas is most likely to be encountered above a pillar fall.
    a) Carbon Dioxide
    b) Methane
    c) Hydrogen Sulfide
    d) Nitrogen Dioxide

10. Because _____ is lighter than air, if not properly diffused, it will rise, stratify and accumulate in inadequately ventilated places.
    a) Carbon Dioxide
    b) Methane
    c) Oxygen
    d) Hydrogen Sulfide

11. What is the principle combustible gas usually found in coal mines?
    a) Methane
    b) Carbon Dioxide
    c) Carbon Monoxide
    d) Hydrogen

12. What is the principal poisonous gas produced by explosions?
    a) Carbon Dioxide
    b) Methane
    c) Carbon Monoxide
    d) Hydrogen

13. Carbon Monoxide causes injury to life by combining with the hemoglobin of the blood and excluding Oxygen.
    a) True
    b) False

14. What is the weight of one cubic foot of Carbon Monoxide at 60 degrees Fahrenheit and 30.00 inches of mercury pressure?

    a) Eleven hundred seventy ten thousandths (0.1170) pounds
    b) Seven hundred forty ten thousandths of one pound (0.0740)
    c) Fifty-three ten thousandths (0.0053) of one pound
    d) Four hundred twenty-four ten thousandths of one pound (0.0424)

15. Oxides of Nitrogen cause fluid to accumulate in the lungs resulting in asphyxia.
    a) True
    b) False

16. What is the chemical symbol of Nitrogen Dioxide?
    a) NO_2
    b) N_2
    c) CO_2
    d) H_2S

17. What is the threshold limit value for Oxides of Nitrogen?
    a) 5 ppm
    b) 10 ppm
    c) 25 ppm

d) 50 ppm

18. What is the specific gravity of Nitric Oxide?
    a) 1.589
    b) 1.036
    c) 0.5545
    d) 0.0695

19. What concentration of Hydrogen produces the most violent explosion?
    a) 7 to 8 percent
    b) 10 percent
    c) 5 to 15 percent
    d) 4 to 5 percent

20. Which is the heaviest, one cubic foot of Methane or one cubic foot of air?
    a) one cubic foot of air
    b) one cubic foot of methane

21. What gas is odorless, tasteless, non-toxic, colorless and explosive in the concentration of 5%-15%?
    a) Hydrogen
    b) Oxides of Nitrogen
    c) Methane
    d) Oxygen

22. The presence of small quantities of Hydrogen greatly increases the explosive range of other gases.
    a) True
    b) False

23. Which of these gases is not commonly found in coal mines following a mine fire or explosion?
    a) Carbon Monoxide
    b) Carbon Dioxide
    c) Hydrogen Sulfide
    d) Nitrogen

24. Displacement of oxygen by other gases, and consumption by oxidation, including mine fires and explosions are the two main causes of oxygen deficiency.
    a) True

b) False

25. What is the specific gravity of Oxygen?
    a) 1.105
    b) 0.967
    c) 1.529
    d) 1.000

26. Is Oxygen flammable or explosive?
    a) Yes
    b) No

27. Whitedamp refers to which gas?
    a) Carbon Dioxide
    b) Carbon Monoxide
    c) Hydrogen Sulfide
    d) Methane

28. How much Methane is present in a Firedamp atmosphere?
    a) 5% - 15%
    b) 30% - 70%
    c) 12.5% - 75%
    d) 4.0% - 45%

29. Blackdamp is an atmosphere deficient in Oxygen.
    a) True
    b) False

30. What is the threshold limit value of Hydrogen Sulfide?
    a) 100 PPM
    b) 10 PPM
    c) 50 PPM
    d) 3 PPM

31. Hydrogen Sulfide is not water soluble?
    a) True
    b) False

32. What is the explosive range of Hydrogen Sulfide?
    a) 4.3% - 4.5%
    b) 5% - 15%
    c) 12.5% - 75%

d) None of the above

33. Hydrogen Sulfide is lighter than air.
    a) True
    b) False

34. Sulfur Dioxide is detected by the sense of smell and its effect on the air passages.
    a) True
    b) False

35. Sulfur Dioxide is water soluble and combustible.
    a) True
    b) False

36. What gas is a product of complete combustion?
    a) Hydrogen
    b) Carbon Monoxide
    c) Carbon Dioxide
    d) Nitrogen

37. Respiration is increased as the concentration of Carbon Dioxide increases.
    a) True
    b) False

38. What is the threshold limit value of Nitrogen?
    a) 81%
    b) 75%
    c) 50%
    d) 33%

39. Carbon monoxide may be found in small quantities after blasting and will be found after an explosion or in the return from a mine fire and use of diesel equipment underground.
    a) Hydrogen
    b) Carbon Monoxide
    c) Hydrogen Sulfide
    d) Methane

40. The presence of Carbon Monoxide (CO) in a sealed mine area indicates a fire.

a) True
b) False

SPONTANEOUS HEATING

Spontaneous heating of coal is the process of self heating resulting eventually in its ignition without application of external heat. The term is generally used for coal as spontaneous heating of other minerals is rare. When coal is exposed to air, it undergoes oxidation at normal temperature and produces CO, CO_2 and heat. The heat generated is carried away by air. If coal is covered, the heat generated is not carried away. The heat accumulated accelerates oxidation. Gradually coal reaches ignition point. In presence of adequate percentage of O_2, it breaks up into flames.

Locations susceptible to spontaneous heating (U/G & O/C)

1. Crushed pillar between intake and return airways
2. Old workings where coal is accumulated
3. Pillar adjoining a fault
4. Goaf
5. OB dump containing coal and shale
6. Exposed coal bench where cracks are formed due to back break and face is not advancing

Causes of Spontaneous heating in Goaf and Working Areas

1. Large amount of coal is left in goaf
2. Left coal is exposed to air due to incomplete stowing

   Non sealing of subsidence cracks and pot holes

   Leakage of air through inter seam partings in contiguous workings
3. High pressure difference across sealed goaf
4. Coal extraction beyond incubation period

5. Poor ventilation
6. Using coal as packing material

Causes of fire in surface mines

1. Presence of shale and inferior grade coal in OB dump
2. Accumulation of loose coal at toe of idle coal face
3. Large coal stock
4. Fire in HEMM due to poor maintenance
5. Fire in belt conveyor due to belt friction
6. Electrical fire due to short circuit and spark.
7. Fire in brattice due to blown out shot
8. Use of damaged flame safety lamp and misuse of flame safety lamp
9. Explosion
10. Welding in shaft and head gear
11. Dry vegetation

Incubation Period

The period between the time when coal is 1st subjected to conditions favourable for spontaneous heating and the time of indications of heating. Incubation period cannot be measured by any instrument. It is judged by experience. Size of panel is kept such that all coal is extracted within incubation period. Incubation period varies from seam to seam. In Jharia coalfields it is 9 to 12 months.

Detection of spontaneous heating

In return air of every depillaring district and every unsealed goaf

1. % of CO to be measured by DGMS approved automatic CO detector at 7 days interval
2. Air sample to be drawn for analysis for determination of Graham's ratio at 30 days interval. If ratio is steadily increasing, measures to be taken to locate the site
3. Inspection of every depillaring districts on idle days or holidays by competent persons
4. Inspection of unsealed abandoned workings at 7 days interval
5. Inspection of subsidence areas over caved goaf at 7 days interval
6. Installation of telemonitoring system in seams susceptible to spontaneous heating

Precautionary measures in Depillaring districts, sealed goaves, unsealed workings and surface workings

1. Quick extraction
2. Panel size to match extraction within incubation period
3. Proper stowing in goaf
4. Blasting the stooks for regular roof fall and goaf consolidation
5. Regular supervision and maintenance of isolation stoppings
6. Regular air sampling and analysis of sealed off areas
7. Arrangement of adequate ventilation
8. Regular stone dusting
9. Isolation of abandoned areas
10. Appropriate blasting to prevent formation of cracks, over breaks in coal seam and exposed coal
11. Quick removal of loose coal over idle coal bench to prevent accumulation

12. Consolidation of stock by dozer
13. Follow first in first out principle for coal dispatch

Question 3: Percentages of various gases in return air of a normally working are as follows:

Oxygen (O_2)-19.95%
Nitrogen (N_2)-78.72%
Methane (CH_4)-0.93%
Carbon Dioxide (CO_2)-0.39%
Carbon monoxide (CO)-0.005%

Calculate CO/O_2 deficiency and CO_2/O_2 deficiency ratios?

Answer- Atmospheric air

O_2-20.93%
N_2-79.04%
CO_2-0.03%

Oxygen corresponding to 78.72% parts of N_2 will be
$(20.93/79.04)\times78.72=20.85\%$

Oxygen (O_2) absorbed =20.85-19.95=0.9%
CO_2 produced=0.39-0.03=0.36%
And this, expressed as percentage of O_2 absorbed= $(0.36/0.9)\times100=40\%$
CO produced=0.005%
Percentage of CO/O_2 absorbed = $(0.005/0.9)\times100=0.56\%$
By calculation, we get CO_2 Produced/O_2 absorbed as 40% and CO produced/O_2 absorbed is 3%

Result indicate dangerous heating

MINE FIRES

For outbreak/eruption of fire following conditions must be fulfilled:

1. Availability of a combustible material in sufficient quantity
2. Availability of oxygen in desired quantity
3. Presence of a source of ignition of adequate energy

4. Contact of combustible material and source of ignition for some time.

Classification of Fires

Class A fires- These fires involve combustible material e.g. ***timber***, ***coal***, ***rubber***, ***conveyor belt***, other ***carbonaceous material.*** These fires are quenched by water. ***Stone dust*** and ***sand*** may be used if fire is on small scale and in its initial stage. Overhead fires can't be tackled by stone dust and sand.

Class B fires-These fires involve inflammable liquids e.g. ***lubrication oils***, ***diesel***, ***petrol***, other ***fuel oils***, ***greases*** etc. These fires are quenched by an extinguishing agent, which has blanketing or smothering action. Foam extinguishers are best suited for this purpose.

Class C fires- These fires involve gaseous fuels e.g. ***LPG gas***, ***butane*** etc.

Class D fires- These are metal fires such as ***melting iron*** etc.

Class E fires-These fires involve live electrical equipment such as ***electric motors***, ***generators***, ***cables***, ***oil-filled transformers***, ***circuit breakers***, ***electric equipment*** etc. These fires require use of extinguishing agent which is not a conductor of electricity. Water with its normal impurities is a conductor of electricity and should not be used. A foam extinguisher is not recommended. Sand is suitable for smothering such fires in initial stages on a small scale. The best extinguisher is ***carbon gas***. The advantage of CO_2 extinguisher is that it has no adverse effect on insulation or other working part of equipment.

Portable Fire Extinguishers

The common arrangement to deal with fire is provision of few buckets filled with sand and few buckets with water. Under Mine Regulations, portable fire extinguishers have to be provided

1. At every entrance to a mine
2. At every engine room
3. At every landing and shaft bottom in use
4. At entrance to every district of a mine
5. At places where timber, brattice cloth, grease, oil or other inflammable materials are stored

Portable fire extinguishers are of following type:

Soda acid, *CO_2 gas*, *BCF*, *water CO_2*, *dry powder*, *foam*, *CTC*, *water CO_2*

Fires in Mines

Fires in mines may erupt at surface or in underground. Surface fires in coal mines may erupt in

1. Store yards, engine/transformer houses, offices and places
2. Overburden dumps in coal mines
3. Exposed coal in quarries
4. Coal stack
5. Coal in bunkers of coal handling plants

Causes of Surface Fires

1. Short circuit in electrical wiring sparks from welding apparatus or electrical motor.
2. Insufficient care and negligence causes spread of fire.
3. Hot surfaces of electrical motors, steam engines, internal combustion engines in contact with combustible material.
4. Ignorance of eruption of fire in overburden heap. Often inferior grade coal and shale is dumped. These carbonaceous materials in overburden dump may catch fire due to spontaneous heating.

Fires in overburden dumps are noticed at many mines in ***Jharia***, ***Raniganj***, ***West Bokaro.*** The DGMS circulars direct, overburden heaps should be atleast 15 m away from coal face. If a quarry is left abandoned, the coal bench and overburden dump should be separated by digging a trench of 6-10 m wide upto non-carbonaceous and incombustible rock below coal seam. Fire in adjacent mine often spread to unaffected mine through barrier between them.

Preventive Measures

Spontaneous heating in coal stack can be controlled by adopting following measures:

1. Ground should be hard. It should be free from vegetation. A concrete surface is ideal.
2. Coal should be screened. The coal stack should contain coal of one size. Fire erupt easily where coal of different sizes are stacked.
3. Coal stack should not exceed 200t. The height of coal stack should not be more than the critical height. The critical height varies for different grades of coal and lies between 1.5-3.0 m.
4. Coal stack should be cleared on first in first out basis.
5. The coal stack should be compacted by dozer. It retards the oxidation process.

Re-opening of sealed off area

Threats in re-opening sealed off area

1. Fire may revive due to air admission
2. Fire damp explosion may occur
3. Roof fall may occur

4. Persons involved in re-opening are exposed to high temperature, inflammable gas, noxious gas

Precautions

When air sample is collected from sealed off area at regular interval for a longer period & indicates that fire is extinct, a minimum 14 days notice shall be sent to Regional Inspector.

Reopening

A limited area of intake and return stoppings shall be broken by ordinary employed persons under rescue cover. A small amount of air shall be allowed to circulate through sealed off area. Simultaneously air coming out of the return stopping shall be tested by gas detector at 30 minutes interval. Samples shall be sent for analysis. When air samples indicate, conditions of sealed off area are safe, the intake and return stopping shall be broken completely to arrange ventilation of sealed off area. The area shall be inspected by overman or mining sirdar. They shall be accompanied by rescue team. Any smouldering material shall be cooled by water. Once area is found safe in all respect, manager shall inspect the area before ordering normal work.

Coal Dust Explosion

1. Coal dust, when suspended in air as a cloud is capable of bursting into an explosion and propagate it, even in absence of firedamp.

2. It should be noted that for a coal dust to start an explosion the dust should be in form of cloud in the air, So dense that one cannot see through it.

3. The quantity amounts to 30-40 g/m^3 of space.

4. The cloud may not be a large size but its density is important and a source ignition of sufficient intensity.

5. Once cost dust explosion starts, its propagation needs very small quantity of dust, only 1 gram/cc of space.

6. This quantity is so small that no part of a coal mine free from when one occurs as it is impossible to keep a mine free from such small accumulation.

7. For this reason when a coal dust explosion takes place it travels to practically all parts of mine.

8. Such circumstances generally exist after fire damp explosion. This however, does not imply that all gas explosions are followed by coal dust explosions.

Gas Explosions

Jeetpur-1973
Sudamdih-1976

1. Lowest temperature at which a fine dry coal dust can be ignited and can cause flame to travel throughout dust air mixture is 700-800^{0}C.

2. Inflammable of coal dust may be defined as it, ability to cause a flame to spread away from source of ignition.

3. Some coal dust are more inflammable than others.

4. Lower limit of in flammable of cal dust is 1gm/cc, but higher limit is quite high. For bituminous coal it is above 2000 g/m3.

5. Higher limit represents a very thick cloud which is difficult to exist in amine under mining condition.

In flammability of coal dust is dependent upon following factors:

1. % of volatile matter
2. Fineness of particle
3. % of inert or incombustible matter
4. % of moisture
5. % of firedamp
6. Nature and intensity of ignition source
7. Age of dust
8. Condition of dust distribution

Prevention of coal dust explosions

1. Preventing its spread.
2. Reducing formation of coal dust at working faces, haulage roads and elsewhere.
3. Provision of stone dust barriers (or) water barriers.
4. Rendering coal dust harmless by wetting it with water or mixing with inert stone dust.

Measure against Dust (CMR 123)

1. Chain of a coal cutting m/c will always be equipped with complete sets of picks
2. Mechanical coal cutting chain will be sprayed with water jets during cutting.
3. Power operated drills dust trap should be used
4. Wet cutting should be adopted
5. Stone dust used for dusting should not contain more than 5% of free slice.
6. Stone dust should be tested once in there months.

7. Floor, roof, sides of working if not naturally wet, should be stone dusted at intervals so that dust sample at that places have at least 75% in combustible matter in them (Coal< 30% VM on dmmf basis.
8. 85% incombustible matter in them CIf coal has 30% VM on dmmf basis) or places should be sprayed with intervals

CMR 123 (A)

1. A dust plan on a scale of 1:2400 or large scale should be maintained showing areas which are naturally wet, water pipeline spraying as a dust control measure, Areas to be stone dusted at intervals of 24 hors, 7 days, 30 days or 3 months. The area shall be marked by separate colours or codes.
2. Area should be demarcated by notice board.
3. Dust in charge should maintain a daily record of steps taken for dust control. He will also see that before shot firing the area in velocity is sprayed with water.

CMR 123(B)

1. Every return airway lying within 200m of last working face and every haulage, tramming or conveyor road way (if not naturally wet) shold be divided into dust sampling zones of 150m length (or small). Each Zone should be divided in to 3 sections a,b,c zones and sections such be marked on a sampling plan 1:2400 r.f. And they should also be marked underground by notice boards.
2. Representative samples should be collected from every zone and section once a month.
3. In a water sprayed zone, samples should be collected by method of 'strip sampling'.

4. In a stone dusted zone samples should be collected by method of spot sampling.
5. Sampling in charge should be mining diploma holder (minimum qualification).

Application of Stone Dust

1. Stone dust mixed with coal dust, has effect of absorbing heat that would otherwise ignite coal dust cloud and therefore stone dust prevents coal dust from reaching ignition point.

Index of explosibility of coal dust at present is amount of stone dust which must be added to it to make it non explosive.
Index can be expressed in two ways:

- Either directly by weight of stone dust added in kg per kg of dust being tested.
- By percentage of ash content in mixture after stone dust has been added including natural ash content of dust being tested.

Desirable Quality of Stone Dust

1. Easily dispersible to form a cloud in air when disturbed

2. Easily available in large quantities and easily grindable

3. Not injurious to health. Siliceous dust should be avoided. Preferably white in colour.

4. Dust in shale, limestone and gypsum is generally recommended for use.

5. % of in combustible dust in coal/stone dust sample in a mine should be 50%-60% for stone dust to be effected in preventing propagation of flame.

6. Stone dust should be fine, generally 100 mesh and finer.

7. In wet or damp condition water proof dust must be used.

8. Stone dusting of U/g roadways should be carried out at regular intervals. So that top layer is of stone dust.

9. Mechanical distribution of stone dust are recommended e.g Mist spreay (MISTER) manufactured by mine machinery and spreys, Dhanbad (DGMS circular No.68 of 1970)

10. Stone dusting is effective if dust is readily raised in air in form a cloud but wetting of coal dust by water aims at achiving opposite result via. Consolidating dust so that it is difficult to raise in air.

11. Sample of coal dust in mine treated with stone dust should be taken at regular intervals, once a week, analysed to content of stone dust.

DGMS circular has prescribed maximum velocity of ventilating air in a coal mine to reduce density effect of air current and preventing escape of moisture from coal dust.

Table 5: Maximum air velocity at different locations

Location	Maximum velocity
Man hoisting shafts, haulage roads (other the conveyor roads)	8 m/s
Other road ways	6 m/s
Conveyor roads, loading points and transfer point	4 m/s
Working faces in developing in depillaring/ stoping	4 m/s

RESCUE AND RECOVERY

Rescue apparatus provides protection to human breathing system against irrespirable and poisonous gases. The rescue apparatus includes reviving apparatus, self rescuer, gas mask, self contained breathing apparatus.

Rescue Station

Rescue stations have been established at ***Dhansar***, ***Sitarampur***, ***Ramgarh***, ***Parasia*** and other places. Rescue station is equipped with 54 sets of self contained breathing apparatus and 18 brigade members. Rescue station extends rescue support to mines within 35 km radius. Rescue station has following facilities

1. Storage, assembly, testing and calibration of apparatus and their quick transport to mines for recovery work

2. Training-Initial training, refresher training

3. Provide support to rescue rooms in case of prolonged recovery operation.

Rescue Room

Rescue room is established at a mine where >100 persons are ordinarily employed below ground and there is no rescue station within 35 km radius. Rescue room can serve more than one mine within 35 km radius, but the number of ordinarily employed persons should not exceed 5000. Rescue room is used for storage, assembly, calibration of breathing apparatus and other equipment. Rescue room is equipped with 15 self contained breathing apparatus. At least one rescue trained person should always be available at rescue room. Rescue rules require provision of 02 smoke helmets i each rescue room.

Rescue room with Refresher Training Facility

It works for a group of mines situated within 35 km radius and with number of ordinarily employed persons below 5000. It is equipped with 30 self contained breathing apparatus and a brigade of 5 rescue

trained persons. It functions as a rescue station, except imparting initial rescue training.

Rescue Equipment

Self contained breathing apparatus- is worn by each member of rescue team for 2 hours at a time. It is independent of surrounding atmosphere. The apparatus currently in use in India is **BG-174** (1992) and **BG-4** (2002) (Make-Draeger).

Short duration self contained breathing apparatus- is used for inspection purpose. It is light in weight. Example: Travox-120.

Smoke Helmet- It is a sort of helmet. It is a tube breathing apparatus. Oxygen is supplied through a short flexible hose from a point situated in fresh air. It is used for (i) rescuing persons from irrespirable zone, (ii) opening ventilation doors in smoke laden area, (iii) fire fighting. The smoke helmet has mica eye pieces in an aluminium frame. It totally covers the head of wearer. It is provided with a flexible hose of 25 mm internal diameter and 50 mm long (36 mm in Draeger Model). Air is forced through the pipe by hand or foot driven bellows. The exhaled air passes out from the helmet through a loose joint around the wearer. A signal rope is spread by the wearer along with the hose. Signal code is decided before starting work. Bellows or fan should be continuously operated till smoke helmet wearer return to the fresh air base.

Disadvantages

1. The hose may be damaged due to roof fall causing danger for the helmet wearer.
2. It can be used upto a distance of 36 m.

3. No other escape route is feasible in case of roof fall

Resuscitating Apparatus- is used to (i) administer O_2 to an unconscious person, (ii) one who is affected by noxious gases, (iii) one whose breathing is feeble due to electric shock, (iv) one who is buried under debris or drowned due to accident.

Manual methods of artificial respiration have disadvantages. This method cannot be adopted in the atmosphere containing noxious gases. The first-aider may get tired quickly. Artificial respiration may not be uniform. Therefore resuscitating apparatus was developed.

Maxaman Resuscitator- blows O_2 into the lungs of affected person during inspiration phase. The used air is sucked out during expiration phase. The apparatus has 600 L capacity and is 9 kg in weight. The functions are automatic. If air passage is not free, it gives indication. Considering its weight and size, only one apparatus can be carried by the rescue team. It can supply O_2 for 30 minutes.

Self contained self rescuer- It is an escape apparatus for saving own life while escaping from mine through toxic atmosphere. It is a close circuit apparatus. The user does not have to depend on outside atmosphere. It is of two types. (i) Compressed O_2 type, (ii) Chemical type. In compressed O_2 type, O_2 consumed in inhalation is replaced by compressed O_2 supplied by O_2 cylinder of self rescuer. In chemical type potassium peroxide reacts with CO_2 and moisture of exhaled air and generates O_2. As per Mine Regulations, each person entering mine is required to carry a sealed self contained self rescuer attached with his cap lamp belt. After fire occurrence or explosion, the wearer has to break the seal of self rescuer. The self rescuer provides O_2 for 30 minutes. The person should be trained before using the self rescuer.

FIRST-AID

As per Mines Rules 1955, following arrangements are made for first-aid in mines.

1. First-aid room in surface
2. First-aid stations at specified places on surface and in underground
3. First-aid outfit for every overman, mining sirdar, shot firer, electrician and fitter
4. Refresher training to first-aid certificate holders and first-aid training to all employees
5. Ambulance

First-aid Room

As per Mines Rules, first-aid rooms should be provided on surface of every mine which employed more than 150 persons on any day during previous calendar year. It should be situated at a convenient place and should be used for first-aid only. A doctor should be in-charge of the first-aid room. A nurse and a dresser should always be available at first-aid room, when persons are at work in the mine. Each person injured in the mine shall report for examination and treatment at first-aid room, even if he has been given first-aid at work place. First-aid room should have floor area of 10 m^2. It should accommodate all equipment specified in second schedule (table and bench, sink and water for washing, towel, soap, dressing, sterilised cotton, bandage, antiseptic, stretcher, blankets etc.

First-aid Station

First-aid station is a place fixed by Manager for first-aid to injured persons. Every first-aid station is provided with equipment as prescribed in 3rd Schedule of Mines Rules.

1. A stretcher and 02 blankets
2. Sets of splints and triangular bandages
3. One first-aid box per 150 persons
    - Sufficient large and small dressings and burn dressings
    - Sufficient sterilised cotton and adhesive plaster
    - Antiseptic solution
    - Tourniquet, scissors, safety pins etc.

Inundation in mines

Abandoned mines and quarries get filled with water and pose problem for working of mines below and near such water logged areas. In between 1912 1nd 1976 there were 12 disasters due to inundation in India. The worst disaster caused by inundation was Chasnala (1975). 375 miners lost their lives in this disaster.

Most of the accidents resulting in inundation have arisen due to

1. Inaccuracy of Old Plans
2. Lack of Old Plans
3. Errors of judgement of neglect of precautions
4. Sudden burst of dam to hold water
5. Unexpected presence of old shafts, boreholes/drifts connecting old galleries full of water

6. Encroaching, intentionally or unintentionally into workings of adjacent mines by crossing common boundary
7. Sudden collapse of water bearing strata due to faulty method of working or insufficient roof supports.

Plan should not be relied upon fully while approaching common boundary. The safe method is not to take the position of old working till it is properly surveyed. If old working is inaccessible, then survey is not possible.

Inaccuracies of old plans include

1. Decrepit condition of old plans
2. Shrinkage and deterioration of material on which plans have been drawn
3. Omission to show magnetic meridian or true north
4. Omission to show full extent of working
5. Omission to correlate the workings with surface features correctly
6. Absence of spot levels at junctions of galleries and or of surface contours

The Coal Mines Regulations and the Metalliferous Mines Regulations have provided sufficient safe guards while approaching water logged area in same or adjacent mine.

CMR 127

1. Proper provision shall be made in every mine to prevent irruption of water or other liquid from workings of same mine or adjacent mine.
2. Adequate precautions shall be taken against irruption of water or other liquid into the workings.

3. No working shall be done within 60 m of any abandoned working. If the area is properly surveyed and is free from accumulation of water or liquid, then work shall be extended with prior permission from DGMS in writing

4. If heavy seepage of water is noticed in any working area which is not within 60 m of any abandoned working shall be immediately stopped. DGMS shall be informed about such occurrence.

MINE ILLUMINATION

A miner working under conditions of insufficient light over long periods not only impairs his efficiency, but also develops an eye disease known as ***Nystagmus***.

Opencast mines are illuminated by sun in day time and needs some artificial illumination during night time. But an underground mine needs artificial illumination from starting of the mine till its closure.

- Intensity of light- Relative amount of luminous energy given by any source. It is measured in candles or candle power (cd).
- Light source generally gives different intensities in different directions. Hence candle power or candela does not convey correct picture unless direction is specified.
- Illumination-at a source is measured in foot candles or meter candle

One meter candle is the intensity of illumination on a surface 1m distant from a source of 1 candela.

Illumination of a surface (meter candle)

$$= \frac{(Candle\ power\ of\ source)}{(Distance\ in\ m)^2} \times \cos\theta$$

- Illumination at a surface is inversely proportional to square of distance of the surface from source of light and directly proportional to cosθ, where θ is the angle between normal to surface and direction of light rays.
- At 2m distance, illumination would be $1/(2)^2 = 0.25$ meter candle

A meter candle is also termed a **LUX**

Reflection-When light falls upon a surface, part of it is reflected and absorbed. In case of a transparent body majority of light passes

through. Only that part of light which is reflected is useful for illumination.

A white surface is a good reflector of light and in underground mines, to improve light effect, following places have to be white washed.

1. Every shaft inset and shaft bottom or Siding and every pass which is in regular use
2. Top and bottom of every haulage plane, every regular stopping place, siding, loading, passbye and junction, except within 100m of face.
3. Every travelling roadway.
4. Every room and place containing any engine, motor or other apparatus
5. Every first aid station below ground.

General lighting in mines

1. Surface at pit top/incline top and in every engine room if natural light is insufficient.
2. Below ground-At every place at which tubs are regularly filled mechanically
3. Every light fitting in underground coal mines has to be of flame proof design.

Table 6: Standard of lighting laid down in circular 14 of 1964 by DGMS as follows:

Location	Minimum Avg. Lumen/Sq. Ft.
Pit bottom	1.5-3.0
Main junctions	1.25
Roadways	0.4
Haulage engine and control gear rooms	1.5

1. Flood lighting of depillaring areas (degree 1 gassy mines) 1.5 at floor level.

2. For depillaring areas circular 36 of 1969 by DGMS recommends following arrangements of lighting.

3. Degree 1 gassy mines-Four or more 250 watt bulbs cluster if height of working is over 3m

4. Degree 2 or 3 gassy mines having fire cluster of 25 to 20 cap lamps on a suitable stand, in addition to cap lamps for individual workmen

Table-7: Recommended standards of general lightings in opencast mines

Sl. No.	Place/ area to be illuminated	Manner in which it is to be illuminated	Minimum standard Illumination (Lux)	Plane/Level in which illumination is to be provided
1	General working areas as determined by the manager in writing	0.2	At the level of the surface to be illuminated	
2	Work place of heavy machinery	So as to cover the depth and height through which the machinery of the rig operates	5	Horizontal

3	Area where drilling rig works	So as to illuminate the full height of the rig.	10.0	Vertical
4	Area where bull dozer or other tractor mounted machine works.		10.0	At the level of the crawler tracks.
5	Places where manual work is done	To be provided at the level of the surface on which such work is done	5	Horizontal
			10	vertical
6	Places where loading, unloading or transfer loading of dumpers, trucks or train is carried on		3.0	Horizontal
7	Operator cabins of machines or mechanisms	To be provided up to a height of 0.8 meters from the surface	30.0	Horizontal
8	At hand picking	To be provided up	50.0	On the surface of

	points along a conveyor belt.	to a distance of not less than 1.5 meters from the picker		the conveyor belt
9	Truck haulage roads	To be provided at the level of the road	0.3 to 3.0	Horizontal
10	Rail haulage track in the pit	To be provided at the level of the rail head	0.5	Horizontal
11	Roadways and footpaths from bench to bench		3.0	Horizontal
12	Permanent paths for use of persons employed, etc.		1.0	Horizontal

MCQ

1. Candela is the unit of

a. Luminous flux

b. Luminous intensity

c. Wavelength

d. None of the above

2. The unit of luminous flux is

a. Steradian

b. Candela

c. Lumen

d. Lux

3. One lumen per square meter is the same as

a. One LUX

b. One Candela

c. One foot candle

d. One lumen meter

4. Light wave travel with a velocity of

a. 3×10^{10} cm/s

b. 3×10^{12} cm/s

c. 3×10^{15} cm/s

d. 3×10^{18} cm/s

5. The velocity of the light wave is 3 × 108 m/sec. Illumination level required for precision work is around

a. 50 lm/m^2

b. 100 lm/m^2

c. 200 lm/m^2

d. 500 lm/m^2

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