# Mine Hazard and Safety

FOR 5TH SEM. MINING ENGG.

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# MINE GASES

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## GENERAL ATMOSHPHERE:-

The atmosphere is a mixture of gases that surrounds the Earth. A typical composition of a normal atmosphere is as shown below:

| Gases | % by Volume | % by mass |
|---|---|---|
| Nitrogen | 78 | 79.04 |
| Oxygen | 21 | 20.93 |
| Carbon dioxide and Other gases | 1 | 0.03 |

## UNDERGROUND MINE ATMOSPHERE:-

In underground mines particularly in coal mines the surrounding mine atmosphere contains some toxic, poisonous and water vapours. Besides these the atmosphere also contains dusts, fumes, oil droplets etc.

These contaminants may cause harmful effects on workers working in the mine as some of them have toxic effects whereas some are irritant and poisonous.

**TYPES of GASES in UNDERGROUND MINES:-**

Besides normal air underground mine atmosphere may contain various gases that are classified as:

- Toxic gases - Toxic gases are those gases if breathed in sufficient concentration for longer duration of time will disable or even kill a person. Toxic gases can further be grouped as:

(i) Asphyxiants

(ii) Irritant gases

(iii) Poisonous gases

- **Asphyxiants** are gases that deprive body tissues of oxygen. They are generally divided into two categories, simple and chemical. They are of two types: Simple and chemical. Simple Asphyxiants have no specific toxic effect but act by excluding oxygen from the lungs. E.g. $CO_2$ and $CH_4$.
- **Irritant Gases** induce inflammation in tissues, conjunctiva of eyes etc. e.g. NO, $NO_2$, $H_2S$, $SO_2$, aldehydes etc.
- **Poisonous gases** destroy tissues. e.g. NO, $H_2S$, $SO_2$, CO etc.

**Oxygen ($O_2$):-**

**Properties of Oxygen**

- Colourless, odourless and tasteless.
- Most abundant on earth.
- Slightly soluble in water: 3% by volume at $20^o$ C
- Its density is 1.428 $kg/m^3$

- ▶ Slightly heavier than air
- ▶ It supports life and combustion.
- ▶ Essential in any atmosphere where men work.

**Physiological Effects of Oxygen Deficiency:-**

In Indian mines it has been prescribed by the Indian legislation that the oxygen concentration in any part of the mine shall not be less than 19%. The followings are the physiological effects of oxygen deficiency.

| **Conc. of O2 (% by volume)** | **Physiological effect** |
|---|---|
| 17 | Faster and deeper breathing |
| 15 | Dizziness, buzzing in ears and rapid heartbeat |
| 13 | May lose consciousness with prolonged exposure |
| 9 | Fainting, unconsciousness |
| 7 | Life endangered |
| 6 | Convulsive movements and death |

**Nitrogen ($N_2$):-**

**Properties of $N_2$**

- ▶ Quite abundant in atmospheric air.
- ▶ Colourless, odourless and tasteless gas.
- ▶ It is nearly as heavy as air with Sp. Gravity 0.967.
- ▶ Practically insoluble in water.
- ▶ It is inert: Neither burns nor support life or combustion

- ▶ It is important for the growth of plant and animal tissues.
- ▶ It does not undergo any alteration in the process of breathing.
- ▶ Nitrogen is sometimes used for quenching underground fires.

**Carbon Dioxide ($CO_2$):-**

**Physical Properties:**

- ▶ It is a colourless, odourless gas and bitter in test (slight acid taste).
- ▶ It is one and half time heavier than air and has sp. gr. of 1.52.
- ▶ Highly soluble in water: 100 vol. of water dissolves at $15^0$C 100 vol. of $CO_2$ forming a weak acid.
- ▶ It is not combustible and doesn't support life and combustion
- ▶ Small spaces in lungs absorb $CO_2$ – $CO_2$ in alveolar air is 5.6%. If it increases to 5.8% then breathing is doubled.

**Physiological Effects of CO:-**

- ▶ CO is a very poisonous gas and commonly referred to as the '**Silent Killer**'.

•Its poisonous character is due to its great affinity for hemoglobin (oxygen-carrier) of the blood.

- ▶ Its affinity for hemoglobin is 300 times that of O2.
- ▶ When CO reacts with hemoglobin it forms carboxyheamoglobin (Hb.CO), a stable bright pink compound.

**Methane ($CH_4$):-**

It is also known as Fire damp. It occurs in coal, metal and non-metal mines.

**Properties:**

- It is a colourless, odourless, tasteless and lighter than air (sp. gravity 0.556). It is slightly soluble in water.
- It is inflammable gas burn in air with blue flame. It can also form an explosive mixture with air when concentration is between 5% and 15%. The most volatile explosion of methane and air mixture occurs when methane content is at 10%.
- It is non – toxic but higher concentration may cause suffocation due to oxygen deficiency.

**Physiological Effects of Methane:-**

Methane is not toxic; however it is highly inflammable and may form explosive mixtures with air. High concentrations of the gas in closed spaces may reduce the oxygen percentage in air and cause suffocation. Asphyxia may result if the oxygen concentration is reduced to below 19% by displacement.

**Hydrogen Sulphide ($H_2S$):-**

$H_2S$ is referred to as **stinkdamp.** It is as poisonous as CO and may cause death in a short time if inhaled in large quantities.

**Physical properties of H2S:**

- It is a colourless gas.
- Smells like rotten eggs.
- Slightly heavier than air. Has specific gravity 1.175 and density 1.5 $kg/m^3$.
- It is readily soluble in water: 1 vol. of water dissolving about 3 vols. of H2S.
- It is combustible but does not support combustion.
- The gas burns in air with pale blue flame.

- It forms flammable mixtures when mixed with air: the flammable range being 4.3 to 45%.

**Nitrous Fumes ($No_x$):-**

$N_2$ is physiologically inert; however, under certain conditions it forms several oxides, some of which are extremely toxic.

There are six oxides of $N_2$.These are NO, $NO_2$, N2O, $N_2O_3$, $N_2O_4$,$N_2O_5$.

NO(Nitric Oxide), $NO_2$(Nitrogen dioxide), $N_2O_4$(Nitrogen tetroxide) are having a biting and chocking smell.

They are yellow to reddish-brown in colour and have a smell of blasting powder fumes.

They are easily dissolved by the moisture in mine air.

**Nitrogen dioxide ($NO_2$) is the most toxic of these oxides of $N_2$.**

**Physiological Properties:-**

Nitrous fumes are highly poisonous and 7 to 10 times more toxic than CO.

Nitrogen dioxide ($NO_2$) is 5 times more toxic than nitric oxide(NO).

$NO_2$ combines with the haemoglobin of the blood about 300,000 times more readily than $O_2$ to form an extremely stable compound thereby quickly reducing the $O_2$- carrying capacity of the blood.

Threshold limit value of $NO_2$ is given as 5 ppm as per DGMS circular.

# PROPERTIES OF MINE GASES

| NAME OF GAS | CHEMICAL SYMBOL | SPECIFIC GRAVITY | COM-BUSTIBLE | EFFECT ON LIFE | SOURCE OR CAUSE WHERE FOUND | EXPLOSIVE RANGE PERCENT BY VOLUME | COMMON NAME | HOW DETECTED | COLOR-LESS | ODOR-LESS | TASTE-LESS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Air | | 1.000 | Supports | Supports | Almosphere | None | | | | | |
| Oxygen | O2 | 1.105 | Supports | Supports | 21% of almosphere | None | | O2 detector | X | X | X |
| Methane | CH4 | .555 | Yes | Inert | Coal & rock strata carbonaceous Shale, rotting mine timbers | 5.0% - 15.0% | Marsh gas, fire damp | Methan-ometer | X | X | X |
| Carbon Dioxide | CO2 | 1.529 | No | Poisonous in high concent-ration | Oxide of coal, blasting, mine fires, timber decay, diesel engines, breathing | None | Black damp | Color-imetric analysis | X | X | If high, slighlly acid taste |
| Carbon Monoxide | CO | .967 | Yes | Poisonous | Incomplete combustion, mine fires, explosions, blasting, diesel engines | 12.5% - 74.0% | White damp | CO detector | X | X | X |
| Nitrogen | N2 | .967 | No | Inert | About 4/5 of atmosphere | None | | Analysis | X | X | X |
| Hydrogen Sulfide | H2S | 1.191 | Yes | Poisonous | Explosions, mine fires, blasting | 4.3% - 45.0% | | Hydrogen sulfide detector acetate of lead | X | Sulfur odor | X |
| Nitrogen Dioxide | NO2 | 1.503 | No | Poisonous | Blasting, burning explosives, Burning nitrates, diesel exhaust | None | | Analysis | Brownish red | If high, sharp sweet order | |

# MINE EXPLOSION

**CONTENTS:-**



## INTRODUCTION:-

**Explosion** is a sudden combustion process of great intensity. It is accompanied by release of large quantities of heat energy and development of pressure. In explosion the original gas (methane) and solid substance (coal) is converted instantaneously into gaseous products.

An explosion is also invariably accompanied by violence on a large scale.

**Mine explosions** are generally regarded as a serious and constant hazard in underground coal mines.

In **coal mines**, explosions are caused

- By ignition of firedamp (Firedamp Explosion)
- By ignition of coal dust (Coal dust explosion)
- By both (Mixed explosion)

In **metal mines**, explosions are due to sulphide dust (Iron pyrite)

## FIREDAMP EXPLOSION:-

**Firedamp** refers to the natural gas mixtures emanating from the strata of coal mines.

Such gas mixture consists chiefly of methane ($CH_4$) with small traces of other combustible gases like ethane ($C_2H_6$) and ethylene ($C_2H_4$). Therefore, firedamp is often considered synonymous with methane.

Methane burns in air when ignited with a pale blue flame but when it is mixed with air, it can explode on ignition.

The combustion or explosion takes place according to the equation

$CH_4 + 2(O_2 + 4\ N_2) = CO_2 + 2H_2O + 8N_2$

The optimum or stoichiometric mixture is formed at **9.5%** methane . Methane however forms flammable mixtures with air over a range of approximately **5 to 15 %** .

If the methane content of a methane–air–mixture is greater than 9.5 % , the oxygen present will not be sufficient for its complete combustion and if it is less than 9.5% , oxygen or atmospheric air will be in excess .

A pure firedamp explosion does not extend over a wide area unless there has been emission or accumulation of large quantities of methane .

## CAUSES OF FIREDAMP EXPLOSION:-

The various causes of firedamp explosion in mines may be grouped under the following headings:

- **SHOTFIRING**: Shots not properly placed causing on overcharged and blown out shots with detonator wrongly placed in cartridge shots fixed without examination for firedamp.
- **NAKED LIGHT**: Matches or other contrabands introduced in mine illegally.

- **DEFECTIVE OR DAMAGED SAFETY LAMP**: Broken glass assembled or lamp tempered with exposing outside atmosphere.
- **SPARK in ELECTRICAL APPLIANCES**: Electric sparks due to short – circuit, loose connection of wires can lead to explosion of fire damp if latter present in proper concentration.
- FRICTION: An intensive frictional spark at a high temperature is capable of causing an explosion.
- **FIRE**: Fire in coal mines or spontaneous combustion of coal can cause ignition of firedamp that may lead to its explosion.
- **FOOLISHNESS of MINERS:** Smoking, welding without protection, making fire or opening of flame safety lamp may result in ignition or explosion of firedamp.

**IGNITION TEMPERATURE**: It is the minimum temperature of methane at which the methane air mixture burns in air to give a flame. The ignition temperature of firedamp – air mixture is 650 – $750^0$C. It is not a definite temperature but depends upon the nature of source of ignition flame or spark, shape and size of space where ignition occurs, methane content, temperature of surroundings, pressure, oxygen concentration, presence of other gases etc.

**COWARDS DIAGRAM:-**

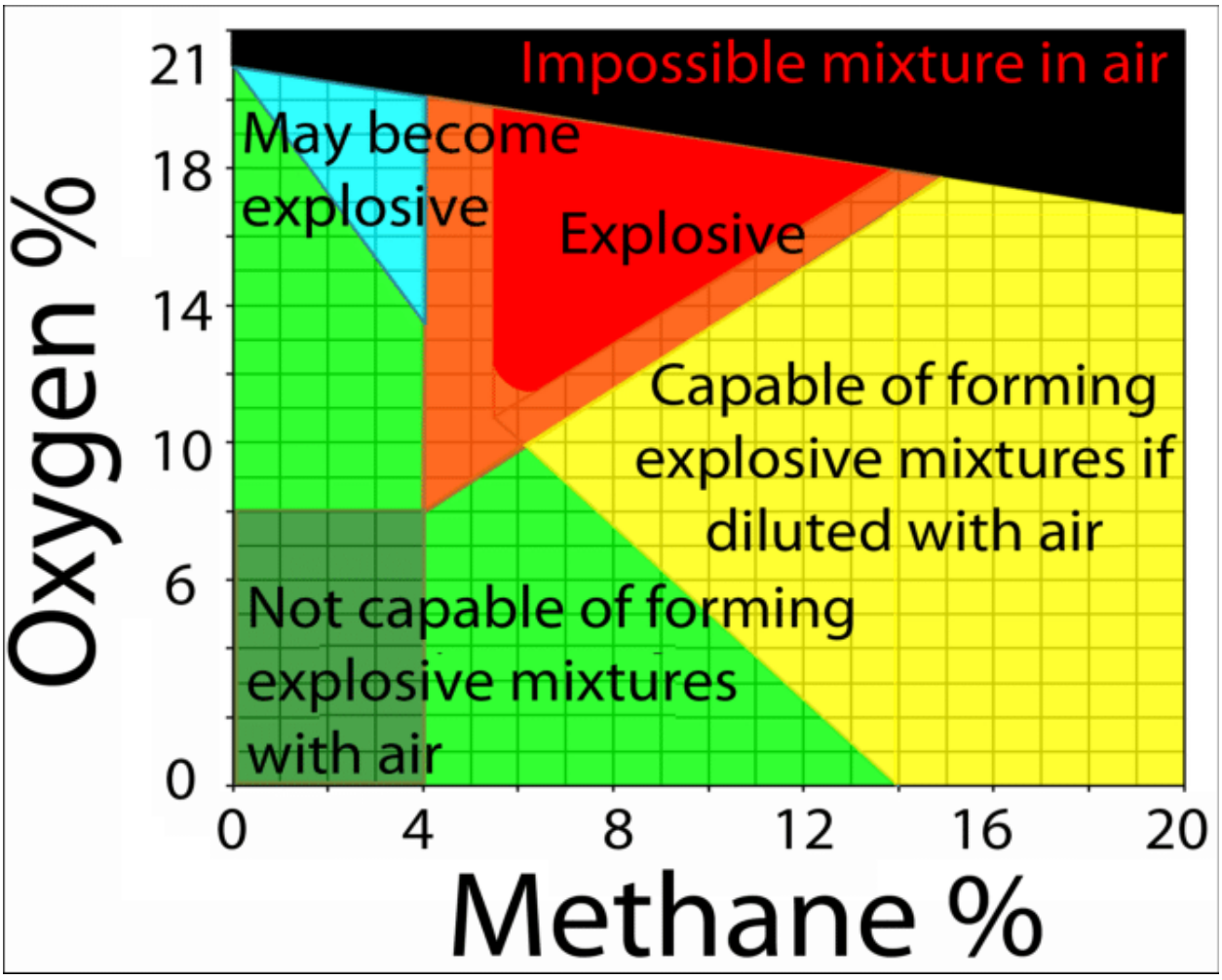
The **Coward** explosibility diagram method is a fast and easy way to determine the explosibility of the mixture of air and combustible gases (Coward & Jones, 1952).

The diagram shows the limits of explosibility with different percentages of firedamp and oxygen.

It has significance

- During sealing off a fire in a gassy mine and
- When reopening a sealed off area.

This diagram explains the probability of firedamp – air mixture in a panel or district of an underground coal mine.




- All mixtures lying within the triangular area XYZ are in themselves explosive.
- All mixtures lying to the right of PYZ contain too much firedamp to explode, but they will form explosive mixtures when mixed with the right amount of air.
- All mixtures lying to the left of PYX are neither explosive nor capable of forming explosive mixtures with air.

- Lower limit of explosibility remains almost constant at about 5.4% for all percentages of oxygen down to about 12.5%.
- The higher limit of explosibility gradually decreases from 14.8% to about 6% with decreasing oxygen percentage.
- No percentage of firedamp is explosive when the oxygen percentage is 12 or less.
- A firedamp – air mixture may become explosive when diluted with an appropriate quantity of air which brings the new mixture within the limits of the triangle XYZ.

**PREVENTION OF FIREDAMP EXPLOSION:-**

No practical measures exist for arresting firedamp explosions in coal mines. Only protective measures against this hazard can be adopted.

The various measures against firedamp explosion hazard in mines can be divided into the following three groups:

i. Measures against accumulation of dangerous firedamp mixtures in mine workings

ii. Measures against ignition of flammable firedamp mixtures

iii. Control of firedamp emission

**Measures against accumulation of dangerous firedamp mixtures in mine workings**

This can be achieved

- by providing adequate ventilation to dilute the firedamp below limits and carry it away to surface. The mine should be mechanically ventilated.
- The sampling of mine air for methane should be carried frequently at several points in the mine.

- If possible an automatic alarm or signal should be arranged against accumulation of methane above threshold limit value.
- Depillaring seams top downward to decrease methane content in mower seams.
- Keeping air leakage as minimum as possible.
- Special examination of layering of methane.

**Measures against ignition of flammable firedamp mixtures**

- All persons should be prohibited from carrying smoking articles, matches or other spark or flame making devices.
- All coal mines should be treated as safety map mines.
- Only approved types of flame and electric safety lamps should be used.
- Flame safety lamp should be properly assembled and carefully brought in mine and always kept in vertical position.
- Only certified flameproof and intrinsically safe apparatus should be used in coal mines.
- The apparatus should be properly installed, protected, operated and maintained.

**Control of firedamp emission**

- Seams with high methane content at great depth should be intensively worked by high production methods.
- Methane drainage techniques to be applied where it is not possible to control methane concentration by general ventilation.

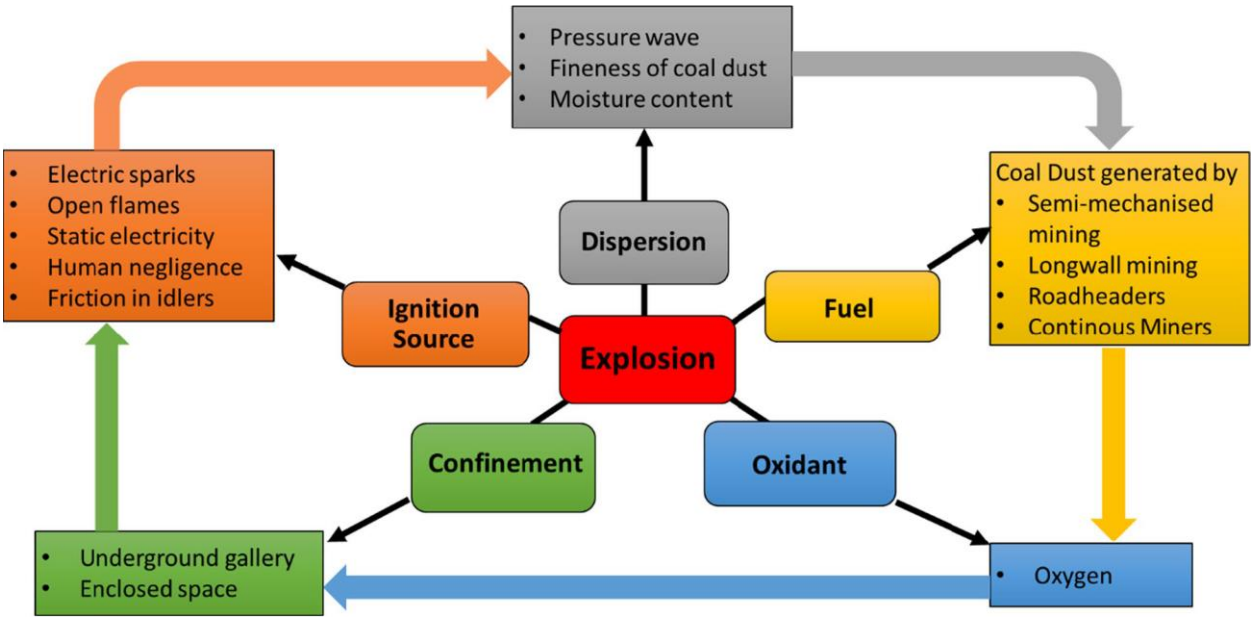
## COAL DUST EXPLOSION:-

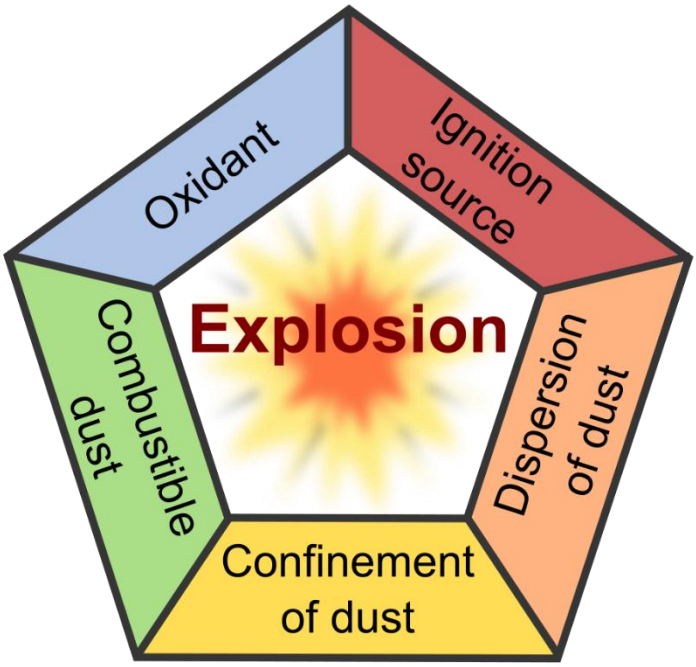
A coal dust or any industrial dust explosion is a sudden combustion process of great intensity characterized by mechanical destructive effects through pressure and heat . For an ignition to take place the combustible dust must be present in the form of a thick cloud having a definite mixing ratio with oxygen , and a source of ignition of sufficient intensity in the form of flame must be present to initiate a combustion wave .

Coal dust suspended in air is explosive -- coal dust has far more surface area per unit weight than chunks of coal, and is more susceptible to spontaneous combustion. As a result, a nearly empty coal store is a greater explosion risk than a full one. The worst mining accidents in history have been caused by coal dust explosions . Such accidents were usually initiated by firedamp ignitions, the shock wave of which raised dust from the floor of the mine galleries to make an explosive mixture.

**MECHANISM:** The coal dust explosion is dependent on five parameters, namely coal dust, air, ignition source, confinement, and dispersion of coal dust. These five factors constitute the explosion pentagon . Figure also depicts the further bifurcation of the five parameters which influence the explosion pentagon. These five factors initiate the explosion and the absence of any one of them rules out the likelihood of a coal dust explosion. Once the explosion has occurred, it propagates throughout the mines under suitable conditions. The mechanism of propagation of coal dust explosion is a chain reaction/domino effect. The shock wave leads the flame front. The shock wave provides energy to the dust particles causing them to disperse. The

lagging flame ignites the dispersed coal dust and this process goes on until it is devoid of suitable conditions.



## CAUSES OF COAL DUST EXPLOSION:-

The various causes of direct ignition of a dust cloud can be classified as under :

A. Naked flames
B. Friction
C. Electric sparks
D. Firedamp explosion

### NAKED FLAMES

A naked flame is the easiest means of igniting a dust cloud as the source of heat is of considerable size and a larger part of the dust clous can be heated.

### FRICTION

Hot surfaces as a result of mechanical friction, such as overheated bearings , may ignite surrounding explosive dusty atmosphere .

### ELECTRIC SPARKS

Electric sparks from short-circuiting and arcing at electrical equipment or overhead trolley wire may ignite an explosive –dust air mixture . Sparks of higher voltage and amperage are necessary than in the case of flammable firedamp mixtures. Static electric sparks can also ignite explosive dust-air mixtures . Fine particles of dust may readily become electrified by friction with air or ducting through which they pass . As the electric charge on a body resides on the surface , a dust cloud has a very large capacity . Under suitable conditions , a discharge or sudden recombination of separated positive and negative charges can occur which can act as a source of ignition . With increasing humidity , the electric potential , however , falls .

## FIREDAMP EXPLOSIONS

A firedamp explosion is the commonest source of initiation of a coal-dust explosion . Besides posing the danger of such direct ignition , a firedamp explosion may raise the deposited dust from the mine floor , sides or roof into mine air very quickly before its flame has ceased and then propagate as a coal dust explosion . A very small gas explosion initiated by accidental ignition of a small quantity of flammable firedamp mixture (approx. 0.4 $m^3$ vol.) may thus bring about a much bigger coal-dust explosion

It is well known that it is much easier to prevent a coal-dust explosion being initiated than being suppressed .

The measures for prevention and suppression (control) of coal-dust explosions can be divided into the following three groups :-

- Measures which prevent or reduce formation and dissemination of coal dust

underground

- Measures against ignition of dust accumulation
- Measures against explosion propagation .

MEASURES WHICH PREVENT OR REDUCE FORMATION AND DISSEMINATION OF COAL DUST UNDERGROUND

- On longwall faces , water infusion of the coal face to reduce respirable dust at low or high water pressures where the seam and adjacent strata allow . The different methods of infusion of coal in – situ before it is mined .
- Wet Winning of coal using wet pneumatic picks where used .
- With machine cutting by means of coal cutters , using sharp picks of suitable type , selecting optimal cutting and travelling speeds of the machine , using gummer and wet – cutting.

When blasting in coal , use of stemming cartridges or ampoules of calcium chloride powder containing 82 to 85 % $CaCl_2$

- Wetting through coal pile before it is manually or mechanically loaded .
- Using such types of conveyors with which the dust production is minimum.
- Preventing spillage and degradation of coal during transport haulage roads.

**MEASURES AGAINST IGNITION OF DUST ACCUMULATION**

These measures comprise :

- Measures against ignition of flammable firedamp mixtures .
- Neutralization of dust at working coal faces within a radius of 10 to 20 m before shotfiring by means of water or inert dust .
- Neutralization of dust in roadways by means of water , inert stone dust and hygroscopic salts .

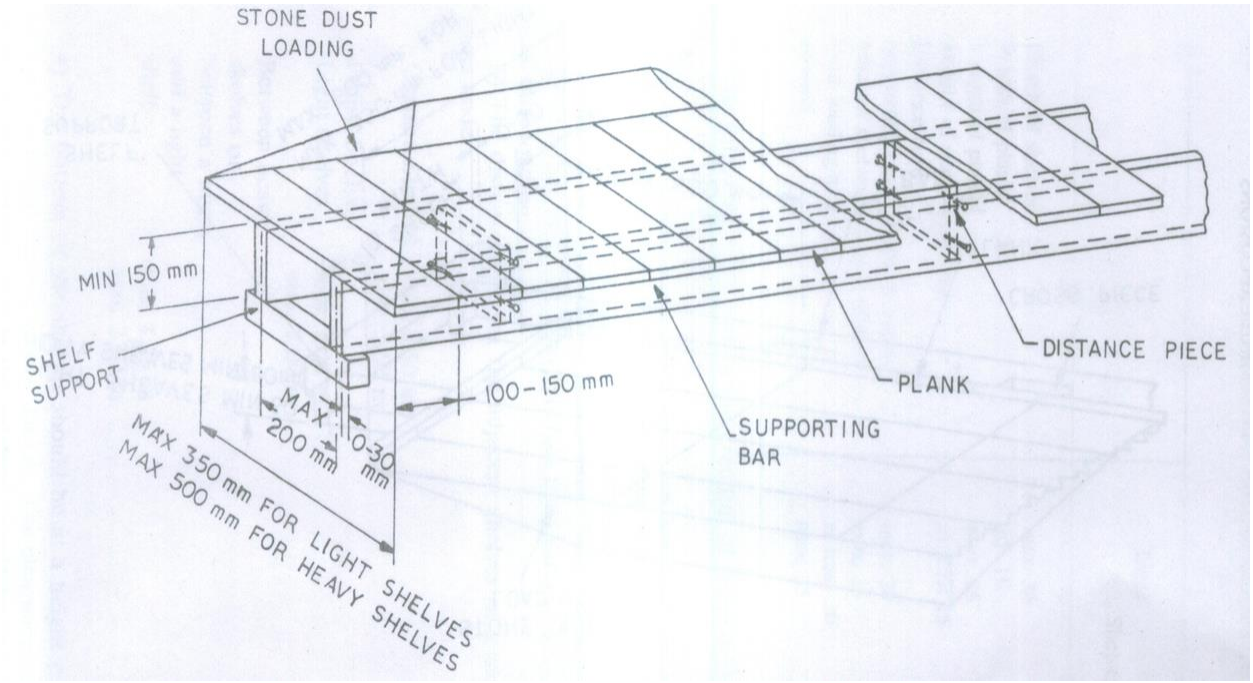
**MEASURES AGAINST EXPLOSION PROPAGATION**

1) Generlised wetting of coal dust
2) Generalized stone dusting
3) Stone dust barriers
4) explosion stoppings
5) Salt zones
6) Water barriers
7) Triggered barriers

## STONE DUST BARRIER:-

**A stone dust barrier** is a device which uses the dynamic pressure of explosion to release and disperse a mass of stone dust in the form of thick cloud into the path of an on-coming explosion flame thereby smothering the flame.

Stone dust barrier are installed in strategic areas of the mine such as roadway leading from shafts or their pit bottoms, in all level and inclined roadways including gate roads and development headings and near roadway junctions.




A stone –dust barrier must carry not less than 400 kg stone dust per square meter of average cross-section of the roadway in which it is installed.

At least a quarter of the total dust loading of any barrier must be distributed on light shelves of the barrier at either end. The heavy shelves must carry at least a quarter of the total dust loading.

The stone-dust barriers are of three types:  The light, intermediate and heavy barrier. Two types of polish shelves are used. The ‘light shelf’ the width of which should not exceed 35cm has a dust loading not more than 29.8kg/m shelf length while the ‘heavy shelf’.

The width of which should not be less than 35cm and not more than 50cm is loaded with not more than 59.6kg/m or less than 29.8kg/m. The light barrier carriers a total loading of at least 107.4kg per square metre of average roadway cross-section and comprises all shelves of the light type. The  intermediate barriers carriers a dust loading of 195.3 kg per square metre roadway cross-section and comprises not more than one-third of the shelves of the shelves of the heavy type. The heavy barrier a dust loading of at least 390.6 kg per square metre of average roadway cross-section comprising not less than one-third of the shelves of the light type.

# SPONTANEOUS HEATING OF COAL

**CONTENTS:-**



## INTRODUCTION:-

Spontaneous combustion is an oxidation reaction that occurs without an external heat source. The process changes the internal heat profile of the material leading to a rise in temperature. This can eventually lead to open flame and burning of the material.

It is a slow process and the heat evolved is carried away by air. This process of self-heating of coal or other carbonaceous material resulting eventually in its ignition is termed as “spontaneous heating” or “auto oxidation”. Coal can interact with oxygen in the air at ambient temperature liberating heat. If the heat is allowed to accumulate the interaction rate increases and may ultimately lead to fires – known as spontaneous fires.

In Indian coal mines, 80% of the coal fires occur due to spontaneous combustion.

The main reason is that the Indian coal seams are thicker and there is a tendency of coal to spontaneous heating during depillaring operation.

Self heating of coal can occur in

- underground mines,
- opencast mines,
- shallow deposits and outcrops
- coal stockpiles,
- transportation and
- at the site of disposal of wastes from coal mine.

**MECHANISM of SPONTANEOUS HEATING:-**

The oxidation of coal, alike all oxidation reactions, is exothermic in eccentric. The nature of the interaction between coal and oxygen at very low temperatures is fully physical (adsorption) and changes into a chemisorption form beginning from an ambient temperature. When coal is disclosed to air it occupies oxygen at the disclosed surface. Some fraction of the exposed coal substance gains oxygen at a faster rate than others and the oxidation outputs in the production of gases. Mainly CO, CO2, water vapour along with the release of heat during the chemical reaction. The rate of oxygen consumption is extremely high during the first few days (particularly the first few hours) abiding the exposure of a fresh coal surface to the atmosphere.

It then downs very slowly except causing problems unless produced heat is allowed to assemblage in the environment. Under certain conditions, the accumulation of fire cannot be combated prevented, and with sufficient oxygen (air) supply, the process may reach higher stages. The coal-oxygen-water complex made during the initial stage (peroxycomplexes) breaks down above 70-85 °C, producing CO, $CO_2$ and $H_2O$ molecules. The rate of chemical reactions and exothermicity change with the rise in temperature, and radical changes take place, beginning at about 100 °C, major due to loss of moisture. This process leads with the rise in temperature, producing more stable coal-oxygen

complexes until the critical temperature is achieved. The ignition temperature of bituminous coal is about 160-170 °C and of anthracite coal nearly 185 °C. Once the coal achieves it ignition point, the air supply to it will only increase the Combustion.

**THEORIES of SPONTANEOUS COMBUSTION:-**

Most important theories of spontaneous combustion:

• The Coal-Oxygen Complex Theory (Rhead and Wheeler)

• Pyrite Theory (Plot)

• The Bacterium Theory (Potter)

• The Phenol Theory (Fischer)

• The Electro-Chemical Theory

**The Coal-Oxygen Complex Theory**

• The establishment of peroxyl radical and hydro peroxides is commonly to be conceived to be the mechanism by which oxygen and moisture are initially incorporate into organic matrix.

• These species may rearrange, react or decomposed to form wide range of oxygen functionality in the gaseous product

- •The following factors favours the oxidation process:
- –Type of coal
- –Temperature
- –Moisture

The following factors favours the oxidation process:

- Type of coal
- Temperature
- Moisture

- At ordinary atmospheric temperature, freshly exposed coal has affinity for oxygen of the air in contact with it.

The oxygen is absorbed by coal on its surface by a purely physical process which, however, rapidly gives place to a chemical chain reaction resulting in oxidation of certain constituents of coal.

**THE COAL-OXYGEN COMPLEX THEORY:-**

• Like all other oxidation reactions, the interaction of oxygen with coal is an exothermic with production of a small quantity of heat.

• The $O_2$ absorption reaction is considered to take place as follows:

**Coal + $O_2$ Coal - $O_2$ complex Oxidised coal + CO, $CO_2$, $H_2O$ + Heat**

**•The heat from oxidation normally varies from 2.0 to 4.0 Cal/ml of $O_2$ absorbed at N.T.P.**

• A rise in temperature of coal, in consequence, takes place which has the effect of increasing further the rate of sorption of $O_2$ and production of heat.

The heat generated, if not dissipated by radiation or conduction or both at a rate faster than it is produced, a further rise of temperature of coal takes place which accelerates further the rate of O2 sorption and production of heat until finally the ignition point of coal is reached.

The ignition temp. of bituminous coal is nearly 160-170°C and of anthracite coal nearly 185°C.

The mechanism of reactions between $O_2$ and coal is quite complicated.

•These reactions occur in following four steps:

•**1st Step:** Formation of coal-oxygen complexes and heat generation.

•**2nd Step:** Decomposition of these complexes, yielding of $CO_2$ and $H_2O$ molecules and formation of more sensible groups [carboxyl (COOH), carbonyl (C=O) and phenolic (OH)] and heat generation.

•**3rd Step:** Decomposition of these groups too (at temp. > 100°C), production of CO, $CO_2$, $H_2$, H=O and high degree hydrocarbons (ethane, ethylene, propylene) and heat generation.

•**4th Step:** Decomposition of aliphatic structure (saturated & unsaturated hydrocarbons), production of CO, $CO_2$, $H_2O$.

**PYRITE THEORY:-**

•Pure pyrite (polysulphide of iron) contains 46.37% Fe and 53.33% S and also reacts with oxygen of air at room temperature emancipating heat and responsible for sp. Combustion.

•Heating of coal could be caused by iron pyrites present in finely powdered and dispersed state in the presence of moisture.

•It has been established that pyrite present in coal might assist the oxidation of its carbonaceous content by breaking down coal into smaller fragments and exposing larger surface area to the air, as well as by elevating the temp. due to heat liberated from its own oxidation.

•The reaction of iron pyrites with oxygen and moisture gives products of larger volume than the original pyrite hence opening more pore area of exposure for oxygen, which is a exothermic reaction.

**$2FeS2 + 7O2 + 16\ H2O = 2H2SO4 + 2FeSO4 \cdot 7H2O + 316 \times 2$ *kcal***

•It also yields reaction product having greater volume than the actual pyrite, with the result that would break open any coal in which they are engrafted and thus exposing a greater surface of coal to the air.

•Sulphonated coal have greater reactivity towards oxygen, especially in the presence of iron oxide.

**THE BACTERIUM THEORY**

- Bacteria also encourage self- ignition of coal due to bacterial action.
- Spontaneous heating observed in haystacks and in wood are known to be mainly due to the activity of bacteria.
- However, there is no conclusive proof to authenticate or dispose this theory. Hence it is concluded that bacteria could cause only a slight heating which may not play any important role.

**THE PHENOL THEORY**

- Many experiments have shown that phenolic hydroxyls and poly phenols oxidize faster than other groups.

**THE ELECTRO-CHEMICAL THEORY**

- It describes auto-oxidation of coals as oxidation-reduction processes takes place in micro galvanic cells made by the coal components.

**FACTORS AFFECTING SPONTANEOUS HEATING:-**

The magnitude of sp. combustion depends on a complex relationship of a range of internal (intrinsic) and external (extrinsic) factors:

**(1) Intrinsic Factors**

- (Nature of Coal)
- Coal characteristics/Seam factors

(2) **EXTRINSIC FACTORS**

- **Atmospheric Conditions**
- **Geological Conditions**
- **Mining Conditions.**
- **Intrinsic Factors (Coal characteristics/Seam factors)**

•Composition, rank and petrographic constituents of coal.

•Friability, particle size and surface area of coal

•Moisture content

•Presence of iron pyrites

•Bacteria

•Other minerals

**Extrinsic Factors (Atmospheric, Geological and Mining Conditions)**

**Climatic conditions:**

•Temperature

•Moisture/relative humidity

•Barometric pressure

•$O_2$ conc.

**Geological factors**

•Coal seam and surrounding strata condition

•Seam thickness

•Seam gradient

•Caving characteristics

•Faulting and other geological disturbances

•Coal outbursts

•Friability

•Depth of cover

**Mining factors**

- Mining methods
- Rate of advance
- Pillar conditions
- Roof condition
- Crushing
- Packing
- Presence of timber or other organic waste material in abandoned areas or dumps
- Leakage
- Multi-seam working
- Coal losses
- Worked out areas
- Heat from machines
- Stowing
- Ventilation system and airflow rate
- Ventilation pressure
- Method of stockpiling and stockpile compaction