

MINE FIRES

8.0 OBJECTIVES:

At the end of the chapter, the student will be able to learn

- Types of fires,
- Causes and Preventive measures of mine fires,
- Spontaneous heating,
- Signs of spontaneous heating,
- Factors for developing Spontaneous heating,
- Causes and preventive measures of spontaneous heating,
- Different methods of dealing with fires and their applicability.

8.1 INTRODUCTION:

Fire constitutes an ever-present hazard in mines. They occur when ever and where ever combustible materials are present in Mine workings. The fires not only endanger the lives of men in a mine but also causes economic loss to the organization.

The losses are two types (i) Direct Losses and (ii) Indirect Losses.

i) Direct Losses:

- 1) Loss of Coal Reserves.
- 2) Loss of mining Equipment.
- 3) Cost of Fire fighting.
- 4) Recovery of sealed-off areas.

ii) Indirect Losses:

- 1) Fall in production from effected areas
- 2) Fall of productivity and increase of cost and usually higher than the direct losses.

For breakout of a mine fire 3 conditions must be fulfilled.

- 1) Sufficient quantity of combustible material must be available.
- 3) Sufficient supply of oxygen must be available.
- 4) A source of ignition must be present.

8.2.1 There are two distinct types of Mine Fires:

- a) Incipient Fires (Due to sp. combustion)
- b) Open fires (Shafts Roadways, faces) visible active combustion or flame.

A) Incipient Fires:

These fires also called seam fires, which originate in abandoned and discontinued mine workings, goaves, fall of roof coal, fractured coal pillars and vicinity of geological disturbances. They account for 75 to 90% of all u/g Mine Fires and difficult to detect in their early stages.

B) Open fires:

These fires originate in open Mine workings such as shafts Roadways, From coal faces and also due to sp. combustion and characterised by visible active combustion flame. They spread quickly in the direction of ventilation the rate depends on velocity of air, quantity of combustible material etc.,

8.2.2 Causes of Mine Fires and preventive measures:

8.2.2.1 Various causes of Mine Fires are

1. Spontaneous combustion
2. Electricity
3. Friction
4. Blasting
5. Explosions
6. Miscellaneous

- 1) **Spontaneous Combustion:** This is the self-heating of the coal or other carbonaceous material resulting eventually in its ignition without the application of external heat.
- 2) **Electricity:** Electric hazards like short circuiting sparking due to improper methods of installation ,use repair, maintenance of electric equipment.

Short circuits and sparks may ignite any combustible material present in their immediate vicinity of place. Safe guards and preventive measures are not installed. It is estimated that over bot are Mine Fires in U.S. Mines occur due to electrical origin.

- 3) **Friction:** Fires due to Frictional causes occur in roadways in which belt conveyors and ropehaulages are installed, in staple shafts which are supported with timber an coal faces which are let by coal cutting machines or power loaders. Belt conveyors Fires Forms the longest percentage of these Fires.

Four main causes of fires due to friction are as follows:

- i) Belt conveyor Fires
- ii) Staple shaft Fires
- iii) Fires in Rope haulage Roadways
- iv) Fires in machine cut and power loaded faces

i) Belt conveyor Fires:

- 1) Due to over heating of driving drum while continuously revolving against the stalled or slipped belt.
- 2) Due to over heating at troughing and return idlers revolving against obstruction.
- 3) Due to over heating of brakes and gears.

ii) Staple shaft Fires:

Fires in staple shafts by friction may occur through as an attended hoist starting, while its brakes are in ON position Frictional sparks may produce at the brake rim which may ignite coal dust setting up on it.

Where a friction hoist is used hot absorbed particles of the rope tread may ignite a file of fine coal dust immediately beneath and file may spread to the support of the engine room and finally to the shaft.

Fires in staple shafts may be prevented by using brake lining an brake tread of fire-resistant materials constructing engine rooms fire proof and providing fire protection in engine rooms and shafts by means of an automatic water sprinkler system.

iii) Fires in Rope Haulage Roadways:

Fires in rope haulage roadways may result from haulage ropes rubbing from frozen rollers and cooling in contact with combustible surfaces such as coal, timber, etc. and from over heated bearings of mine cars. Power selection, installation and maintainances rollers, pulleys and car bearings may prevent them.

iv) Fires in Machine Cut and Power Waded Faces:

- 1) Due to Frictional sparking during arthodox coal cutting operations in seams.
- 2) Due to Frictional sparks produced by the travelling picks ignite inflammable mixture of fire damp or dust.

4) Blasting:

Blown out shots in coal especially when coal dust is present in shot holes may cause mine fires through ejected glowing particles igniting coal dust or loose coal near the face Blasting can also ignite an unknown Methane blower which in then may set an entire coal face on fire.

5) Explosions:

Fire damp and coal dust explosions leave in their wake smouldering and active Fires. . The explosion flame, gases and coal dust take part in an explosion may set on fire on wooden doors, non fire proof pieces of clothing, un burnt coal dust and loose coal an ultimately to coal faces.

6) Miscellaneous:

- i) Careless handling of naked lamps or open lights, carrying matches, other flame making devices, smoking, causes fires.
- ii) Welding, cutting, soldering operations with arc or gas in u/g may result the mine fires.
- iii) Static or Frictional electricity, may result fires.
- iv) Friction of belts against pulleys produces sparks.
- v) Goaf fires may originate due to ignition of coal dust.

8.2.2.2 (ii) Preventive Measures of Fires:

- a) **Spontaneous Heating:** This is controlled by proper winning of coal, not leaving carbonaceous matter, high rate of extraction, roof control, adequate ventilation.
- b) **Electricity:** Proper methods of installation, regular inspection, good maintenance, provision of safe guards minimise electrical Fires.
- c) **Friction:** Lubrication of rollers, good maintenance minimizes frictional fires. Using fire resistant material, Installing automatic fire sensor system, installing safety devices, maintaining correct alignment, keeping idler rollers will also reduce these fires.
- d) **Staple pit fires:** Fires in staplepit may be prevented by using brake lining and rope treated with fire resistant materials, constructing fire proof engine rooms, and providing fire protection in engine rooms and shafts by means of an automatic sprinkler system.
- e) **Fires in Rope Haulage and Inclined Shafts:** proper selection, installation and maintenance of rollers, pulleys and axle bearings may prevent fires.
- f) **Miscellaneous:** As a precaution against welding, cutting soldering, they are performed by competent people, under the supervision of qualified persons at places free from danger due to fire damp or coal dust. Adequate fires extinguishing appliances and using of stone dust reduce fires.
- g) Friction of belts and the dangers can be minimised by installing all machinery so as to secure a safe discharge of static electricity.
- h) Diesel powered equipment shall be maintained properly, malfunctioning shall be repaired immediately.

8.2.3 Spontaneous Heating :

Spontaneous combustion may be defined as the self heating of coal or other carbonaceous material resulting eventually in its ignition without the application of external heat or of any oxidisable substance due to auto-oxidation at ordinary atmosphere, temperature.

Physico-chemical process plays an important role in spontaneous combustion.

When coal is exposed to air it absorbs oxygen termed as oxidation. This oxidation results in formation of gases CO, CO₂, H₂O and evolution of heat during the Chemical reaction.

The most important theories of spontaneous heating are:

- 1) Bacteria theory
- 2) Pyrite theory
- 3) Phenol theory
- 4) Coal-oxygen complex theory

Freshly exposed coal has affinity for oxygen as it is absorbed by coal on its surface by a purely physical process which rapidly gives place to a chemical chain reaction resulting in oxidation of certain constituents of coal with production of certain of a small quantity of heat.

A rise in temperature of coal in consequence takes place which has the effect of increasing further the rate of absorption of oxygen and production of heat. A further rise of temperature of coal by radiation or conduction process or by both takes place which increases further the rate of oxygen absorption and production of heat until finally the ignition point of coal is reached.

200°C → For Bituminous coals

398° → For Anthracite coals.

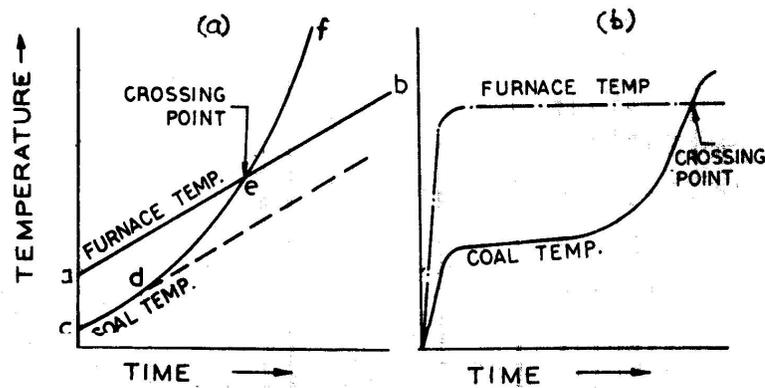
Leakage of air is an important condition for sp. heating to take place in mines such a condition exists in goaves of coal seams worked by the bord and pillar method with open caving of the Goaf or geologically disturbed zones.

Relative liability to sp. heating of different coals has following properties.

- 1) Critical Oxidation temperature (or crossing point)
- 2) Ignition Temperature (Ignition point)
- 3) Rate of oxygen quantity absorbed.

1) Crossing Point:

The crossing point of coal is the temperature, of which, the temperature of a powdered bed of coal, with oxygen or air, passing through it at a predetermined rate crosses the temperature of the furnace in which the sample is heated at constant increasing temperature.



1) **Ignition temperature:** The ignition temperature of the coal decreases with increasing oxidation of coal.

2) **Quantity of Oxygen absorbed:**

The amount of oxygen absorbed and the oxidation rate of coal had been employed for determining relative liability to sp.heating of different coals by some investigations.

8.2.4 SIGNS OF SPONTANEOUS HEATING:

The symptoms or signs can be generally considered in the following stages

a) **Initial stage of heating:**

i) **Faint haze:** This is due to moisture given off during oxidation of coal. The moisture collects as small globules in the cooler air away from the actual seat of heating.

ii) **Moisture deposition:** This is due to condensation of moisture and its deposition as beads on the cooler surfaces.

iii) **Faint odour known as gob stink:** The odour resembles the smell of decaying timber. There is also slight discomfort due to increase in air temperature and humidity.

iv) Cricket and other small insects show increased activity and chirping

b) **Intermediate stage:** Previous symptoms are intensified and there is a further pronounced petrol-like smell indicating the beginning of distillation of coal.

c) **Last stage of heating approaching ignition:** Petrol like odour changes in to tarry odour, known as fire stink which is also due to distillation of coal. Further stage is the actual appearance of smoke.

8.2.5 Factors Effecting Liability of coal to Spontaneous Combustion:

A Survey in different countries has established that 75% to 85% of Mine Fires are caused by spontaneous heating .The factors are as follows.

- 1) Presence of Iron Pyrites
- 2) Area of coal surface
- 3) Freshness of exposed coal surface
- 4) Rank of Coal
- 5) Volatile content
- 6) Petrographic composition of coal
- 7) Oxygen content
- 8) Moisture content
- 9) Temperature of Atmosphere
- 10) Ash content.
- 11) Influence of Rock pressure
- 12) Ventilation
- 13) Friability
- 14) Nature of Adjoining Strata
- 15) Depth of seam
- 16) Thickness of seam
- 17) Geological disturbances
- 18) Time factor
- 19) Method of working
- 20) Leakage of air.

1) Presence of Iron Pyrites:

Iron pyrites swell and cause the coal to disintegrate during oxidation. They very in very small quantities in coal seams. Later investigations made that sp combustion of coal could takes place even without presence of pyrites. But oxidisable Iron sulfide has only a promoting effect on Auto oxidation of coal

2) Area of Coal surface:

The rate of oxidation and rate of heat liberated depends on the surface area of the coal greater the area of surface in contact with the air greater will be the rate of oxidation and susceptibility to sp. combustion. In bituminous coal sp. combustion is high for sizes less than 38 mm.

3) Freshness of Exposed coal surface:

The rate of oxidation of exposed fresh surface of coal increases continuously during the progress of oxidation i.e., with time.

4) Rank of Coal:

High rank coals like Anthracite and Bituminous (% of carbon > 85) are less liable to sp. heating where as low rank coals such as, lignite and sub-bituminous coals are more susceptible to the sp. heating.

5) Volatile Content:

Oxidation rate increases if volatile content of coal increases, coal with 38% of v.m oxidises 3 times as fast as coal with 18% v.m. Another research found the v.m of less or greater than 28% is more liable to self-heating.

6) Petrographic composition of coal:

Out of these banded constituents the bright bands of coal, vitrain and clarain are more liable to self-heating, than dull constituents.

7) Oxygen Content: S

Oxidation rate decreases with decreasing O₂ percentage in coal content. With oxygen content 2% or less the coal is not liable to self-heating. If O₂ % increases self-heating also increase.

8) Moisture Content:

High moisture coals are more susceptible to self-heating. Experimentally proposed that at non-temperature absorbed moisture exert an effect on the oxidation process.

9) Temperature of Surrounding Atmosphere:

Warm air in contact of exposed surface of coals considerably increases the oxidation rate with the process of conduction.

10) Ash Content:

Ash in coal generally decreases the oxidation rate, which is also influenced by the Mineral composition of the ash.

11) Influence of the Rock Pressure:

Excessive rock pressure acting on the pillars resulting in their crushing was a source of heating. Rock pressure increases the surface area of coal exposed to oxidation.

12) Ventilation:

Weak air current helps to oxidation process but not sufficient to keep down the temperature.

13) Friability:

Coal is easily crushed and broke into smaller size is more liable to self-heating than hard coal.

14) Nature of the adjoining strata:

Thermal conductivity of coal measure shales is only 1/3rd that of the sand stone. If coal heap is covered by loose shales the heat of oxidation of coal is not dissipated as fast as in the case of coverage of sand stone and former heap is more liable to self-heating.

15) Depth of Seam:

The strata temperature and crushing effect increases with the depth, which are the prime factors to accelerate self-heating.

16) Thickness of Seam:

Percentage of extraction) during depillaring by caving is about 50% only. Remaining coal is left in the form of stooks or shale coal in u/g due to poor marketability also responsible for self heating.

17) Geological Disturbances:

Due to fault plane the coal is crushed. Some coal is left as support near the fault zone. Such coal is more liable to self- heating.

18) Time Factors:

It is common experience that a certain time must elapse before the first signs of heat appear.

19) Method of working:

The method of working greatly influences the self- heating of coal. In bord and pillar mining the sp.heating is comparatively more liable than Long-wall.

20) Leakage of air:

Fractures in coal pillars, doors,regulators may cause leakage of air, that leads to self-heating of coal.

8.2.5.1 Stages of Spontaneous Combustion of Coal in Mines:

Three Stages are.

- 1) The incubation period
- 2) The indication period
- 3) Open fire.

1) The incubation period:

As soon as first falls takes place in to the goaf , conditions are created in which the rate of production of heat exceeds the rate of dissipation of heat.This is said to be beginning

of incubation period. The incubation period is the period of time beginning from the time the coal is buried in the goaf (i.e. from the time when first major fall takes place in the goaf) to the time when preliminary symptoms of heating are detected.

It is the period between the beginning of coal extraction in a district or panel and appearance of first signs of heating.

The incubation period depends on the seam thickness, nature of the immediate roof, method of working, method of roof control, regularity and continuity of working and liability of coal to self-heating. Generally incubation period varies from 8 weeks to 24 weeks or 1 year.

Ex:- 1. Niveli Lignite mines—8-10 weeks

While deciding the size of the panel/pillar the incubation period of the coal seam is to be considered. The size of the panel so fixed that the entire panel can be extracted within the incubation period without the occurrence of sp. heating. The period in Indian Coalfields generally varies from 6 months to 12 months.

The high volatile coals of Raniganj, shorter incubation period and the low volatile coals of Jharia Coalfields have longer incubation period. For lignite the incubation period may be few weeks only.

ii). The indication Period:

The end of the incubation period that is the beginning of the indication period is marked by sweating by the warm up air from a fire area cooling on come into contact with the cooler coal, rock and metallic surface and deposition moisture.

The indication period is often of very small duration i.e., about only a few hours.

iii) Open Fires:

It comes to an end with the appearance of “Fire Stink” when open fire with visible active combustion breaks out. The fire stink can be easily recognised by its characteristic petrolic smell with tarry odour. Appearance of smoke, increased temperatures, seams bluen with a bright flame but they glow developing bluish white clouds of smoke.

8.2.6.1 CAUSES OF SPONTANEOUS HEATING:

- 1) OXYDATION OF COAL
- 2) INSUFFICIENT VENTILATION
- 3) METHOD OF WORKING
- 4) ROOF FRACTURES OR COLLAPSES
- 5) IMPROPER SUPERVISION.

8.2.6.2 PREVENTION OF SP. COMBUSTION OF COAL IN MINES:

- 1) Development
- 2) Coal-Winning
- 3) Roof-control
- 4) Ventilation
- 5) Inspections

1) Development:

- i) Un necessary splitting of seams must be avoided all coal surfaces not being worked must be protected against absorption oxygen by stone dusting or coating with as anti-pyrogene.
- ii) When seams are working by bord and pillar method following points are absorbed.
 - a) Dimensions of pillars are so that no crushing of pillar takes place during extraction.
 - b) Panels with independent ventilation must be formed as far as practicable.
 - c) Panels must be laid as to minimise serves crushing of coal during extraction.
 - d) Panel size should be such that the complex extraction should be done before incubation period.
 - e) The development cause should be kept out of abutment areas.
- iii) The roof of roadway in coal should be well supported and the sides are lagged.
- iv) When travelling in seams in cross cuts, coal should be removed to adequate depth and the cavities formed should be filled or packed with clay or other incombustible material.
- v) Side by side intakes and returns must be avoided , main intake and return air ways and main haulage roadway should be driven in stone as far as practicable.

2) Coal Winning:

- a) The coal should won as completely as practicable especially in disturbed zones and steep seams.
- b) The working faces should be worked to extract high percentage of extraction. If any roof fall is interrupting coalface advance or retreat immediate steps should be taken to overcome the obstacle.
- c) When mining a group of seams the workings in upper seams should be in advance of those in the lower seam and also the coal in upper seam should be completely extracted.
- d) The best method of working seams is the longwall and stall methods.
- e) When working by longwall, the retreating longwall method should be preferred to eliminate leakage of air current through goaf.

- f) When working a seam by Longwall advancing the gate side packs should be made airtight.
- g) Worked out areas should be effectively sealed off as soon as possible or ventilated well.
- h) Blasting in coal must be restricted as much as possible.
- i) In bord and pillar workings, the pillars should be extracted as fast as possible.
- j) Partially built seals or preparatory stopping should be extracted in the entries of panel fire barriers before extraction is commenced.

3) Roof Control:

- 1. Solid stowing is the best method for working seams liable to self heating.
- 2. In Longwall caving the gate roads should be supported with tight road side packs.
- 3. In bord and pillar working with open caving of goaf, a straight line of fracture should be maintained.
- 4. Native or foreign oxidisable materials should not be discovered into the goaves.
- 5. Washery dirt used for stowing must be fire proof. It should be mixed with stone and stowed.

4) Ventilation:

- i. All active mine workings must be adequately ventilated.
- ii. Ventilation pressure should not be great so that leakage through crushed or defective pillars is less.
- iii. Short circuiting of air as well as its uncontrolled circulation must be eliminated.
- iv. Every roadway in coal should be ventilated and unused roadways are sealed off.
- v. Roadways in coal should have suitable size and air currents in them have sufficient velocities to have necessary cooling power.
- vi. Ventilation stopping should be correctly constructed.
- vii. Air crossing should be constructed of fireproof material.
- viii. Mine Ventilation should be efficiently supervised.

Inspections:

- i. Every working place in u/g should be inspected by a supervisory official of lay a competent person at least once during each shift.
- ii. On idle days all districts liable to self heating should be inspected at least once by competent person.

8.2.7 Different Methods Of Dealing With Fires And Their Applicability:

- i) Fighting by direct attack –applicable when fire is small and easily approachable.
- ii) Fighting by indirect attack-applicable to fire is large and not approachable.
 - a) Isolation of the fire.
 - b) Sealing the fire area or the entire mine.
- iii) Flooding the fire area or the entire mine. –applicable when fire spread to entire mine
- iv) Flushing the fire area with sand or other suitable solid materials conveyed with water.-applicable to fire is small,easily accessible
- v) Introducing inert gas into the fire area.-applicable to fire is wider extent,not approachable.
- vi) Special methods of fire fighting.-applicable to special conditions.

8.2.8 Dealing With Underground Fires

When the foreman/overman, or Asst. Manager notices any indication of heating or fire in any part of a mine he should withdraw workers from the ventilating district and the area likely to be affected (e.g., are on the return side of the ventilating district), cut off electric power to that area and inform the mine manager. Symptoms of heating or fire are more pronounced on the return side of the fire or place of heating. One method of informing all the workers of the emergency is to pour eucalyptus oil in the intake air stream. The smell which spreads in no time to all the parts of the mine with ventilating air current warns the workers. Such steps are taken in the mines of Kolar Gold Field.

The mine manager, on getting information of fire, has to inform the J.D.M.S. and also the nearby rescue station if he considers the presence of the rescue brigade essential; in any case, he should advise the rescue station to keep the rescue brigade in reserve even if the fire is small and may not demand immediate arrival of the rescue team.

The following measures may be taken in dealing with the fire :

(A) Quenching the fire with water, sand or with the suitable fire extinguisher. This direct attempt is justified if the fire is small and accessible. Ventilation to the fire area is restricted by short circuiting the major quantity of ventilation. The fire should be tackled only from the intake side, and water should not be used to quench electrical or oil fires. The quenched material is dug up and sent to the surface in specially marked tubs/mine cars. The dug up area is trenched with water and allowed to cool down. The cavity is packed with sand or earth. During the process of the fire fighting, flame safety lamps and CO detecting apparatus, or alternatively small birds for CO detection, should be kept at the site. Digging out if possible of (1) The fire is easily accessible, (2) Localised over a small area (3) There is no danger of firedamp explosion, and (4) The roof is good and has not collapsed due to fire. Accidental fires, if detected in time, are not extensive and can generally be dealt with by the direct method of attack. A small accessible fire can be covered with a blanketing material like earth or sand to starve it of oxygen. The blanketing has to be done not only on the burning material but also at the cracks or passages of air supply to the fire. In one case where flames were seen emerging from the roof of a roadway, air entry to the fire was found to be through cracks about 30 m away.

If the fire cannot be tackled by the above method one of the following measures has to be adopted.

- (B) Sealing off the fire.
- (C) Drowning the fire.
- (D) Flooding the fire area with inert gas.

(B) Sealing off the fire:

If the fire is inaccessible, e.g., in a goaf area, or if it is extensive, or if there is danger of firedamp explosion when dealing with it, it has to be sealed off. The aim is to prevent access of air to the fire and starve it of oxygen. The sealing operations have to be conducted from places which will not be affected by the effects of fire like heat, smoke, CO, CO₂, etc. A large area has therefore to be sacrificed during sealing though it may be recovered later when the fire is extinguished and the area cooled down. Time factor is important in sealing. Delay will cause the fire to spread over a large area and the extensive fire may go out of control resulting in abandonment of the mine; it may spread to adjacent mines as well in a explosion.

The stoppings constructed to seal a fire area are of the following types depending upon the purpose they serve.

- 1) Preparatory stopping.
- 2) Emergency stopping or temporary stopping.
- 3) Permanent stopping.

Preparatory stoppings are partially constructed in the main entries leading to a district, generally before depillaring is undertaken. After the depillaring operations are over such stoppings are made complete to isolate the depillared area and are then called *isolation stoppings*. Bricks and earth are always kept in readiness at such stopping sites. Since the preparatory stoppings serve ultimately the purpose of isolation they are often called *isolation stoppings* even when they are partially constructed and are not actually isolating an area. The preparatory stoppings have to be provided in all mines. Whether depillaring is to be carried out with caving or with stowing. Where depillaring with caving is planned such a stoppings should enclose an area and form a panel from which all the coal can be extracted during depillaring within the incubation period. If depillaring with stowing is planned, the area enclosed is permitted to be much larger (D.G.M.S. Circular No. 55 of 1962). A preparatory stopping should be provided with an iron door which is generally taken off the hinges and kept beside the stopping. In case of an emergency like fire in the panel the door is very handy in isolation the panel from the rest of the mine. An isolation stopping in Cat. I & II gassy coal mine should be of a minimum thickness of 1 m, brick, cement or lime. Regular air samples should be taken from behind the sealed area and whenever it is found an analysis that CH₄ % has increased to 2 or more, the stopping should be strengthened so as to make it explosion proof. In Cat. III gassy coal mine, an isolation stopping should be explosion-proof.

An explosion proof stopping should consist of a pair of two brick stoppings built in cement mortar having minimum thickness of 1 m and spaced at least 4.5 m apart. The intervening space between the two stoppings should be packed solid with incombustible materials. (There should be no coal pieces or other carbonaceous matter in the packing.)

The isolation stoppings should be well keyed into the roof, floor and sides, and for this purpose, the minimum depth of locking should be as follows:

- (i) In coal 1.0 m
- (ii) In sand stone roof/floor, 15 cms.
- (iii) In shale stone roof/floor, 30 cms.

Emergency Stoppings or temporary stoppings are constructed after heating or fire is detected. Such stoppings are required where preparatory or isolated stoppings had not been constructed e.g. in a development area where there is no necessity of their construction. The purpose of an emergency stopping is to seal an area immediately and prevent access of air to the fire which lies down in course of time. It also prevents the heat, smoke and fumes from reaching the places where permanent stoppings have to be constructed. The temporary stoppings have to be built at places which are free from ground movement and free from cracks as such cracks provide passage of air to the fire. If a place free from cracks is not available the cracks should be sealed.

- (1) by guniting, i.e., spraying the surface with liquid cement sand mixture (sand:: cement in the ratio of 3:1), or
- (2) by spraying the surface with Latex (a trade name) with the help of compressed-air-operated gun.

Both these methods require compressed air which may not be available underground in most of the coal mines, as electric power is the common practice.

Pillars with cracks are common in the vicinity of depillaring areas. Stopping areas and also in other areas which are subject to crushing due to small sized pillars or robbing of coal and heightening/widening of galleries.

8.9.i) Sealing a fire in a non-gassy mine (deg.1 gassy mine)

The method of sealing a fire depends upon whether the mine is gassy or non-gassy. In a non-gassy mine or Cat. I mine the standard practice is to immediately stop air supply to the fire by construction of temporary stoppings in the intake and return roads of the district and in other roads through which air may have access to the fire. This is followed by construction of permanent stoppings. During such work all workers in the ventilating district affected by the fire should be withdrawn.

Construction of temporary stoppings:

These are constructed in one of the following ways:

- (1) Stopping made by nailing wooden planks to timber props.

- (2) Stopping made of C.G.I. sheets fastened to timber or rail props and having piles of sand or stone dust bags behind them.
- (3) If stone of ripping is available in underground, a pack wall of stone plastered with earth or cement.
- (4) If sufficient number of bricks are available in underground, in a near by place because of previous storage, a stopping of brick-in-mud.
- (5) A stopping consisting of a close-knit wire mesh stretched across the roadway and sprayed with Latex sealant.
- (6) A pre-fabricated stopping of tongues and grooved wooden boards.
- (7) A sand bag stopping. This is common and easily constructed. Empty cement bags are filled to half their capacity with earth. Such half filled bags are easy to carry and they make a compact packwall when piled on over another. The surface of the packwall is plastered with earth or cement.
- (8) Gypsum stoppings, These are constructed of a quick setting gypsum. They have been tried successfully in foreign countries like Germany and U.K. this type of stopping consists of two tight shutterings between which is injected dry gypsum powder by compressed air driven guniting machine. As the gypsum powder is being injected, water is added up to form a slurry which soon sets and forms a hard mass. The recommended thickness of stopping is: 2m for roadway height up to 3 m; 2.5 m for roadway height up to 3.5m.

For every m³ of stopping volume about 1.3 te of gypsum and 1 m³ of water is required.

The gaps between the shutterings and pillars of coal/mineral are packed with gunny bags to prevent the slurry from flowing out. A sampling pipe is to be provided through both the shutterings.

Such stoppings is simple and easy to erect.

The construction of fire stoppings in an emergency calls for a good streamlined organisation. The following points should be noted.

- (1) Stores should have adequate stock of bricks, cement, C.G.I. sheets, rails, sleepers, empty cement bags, stone dust, etc.,
- (2) Haulage track should be extended to the stopping site for transport of heavy quantities of bricks, cement, sand, earth, etc., It may some times be necessary to install a small haulage also.
- (3) Work of stopping construction should be done by workers who should not work overtime. A plan should be drawn out to decide the number of workers required and their shifts. It may be necessary to take help from adjacent collieries, specially in respect of rescue trained workers and stores materials. An Officer should be incharge of man power and allotment of the duties of different worker, the arrangement of their shifts, etc.,
- (4) At the site of stoppings the following equipment should be provided: (I) Flame safety lamps for detection CH₄ (ii) Birds for detection of CO₂ (iii) sufficient stone dust and fire sealing materials, like bricks, cement, sand, earth and tools of masons, carpenters,

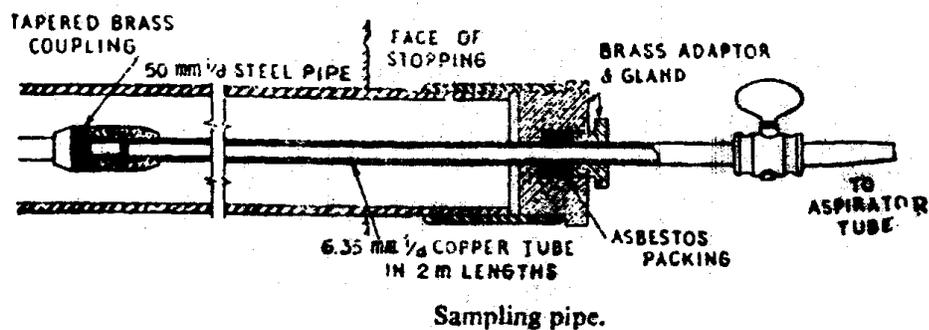
miner, and other worker, (iv) First aid boxes and stretchers, (v) Extra electric cap lamps as some may become dim after 5 or 6 hours used, (vi) smoke helmets and other apparatus required by rescue party, (vii) Drinking water and snacks, (viii) Mine plan and tracings of fire area on a large scale.

Telephones should be extended up to the site of construction. The work should be done under the supervision of experienced officer.

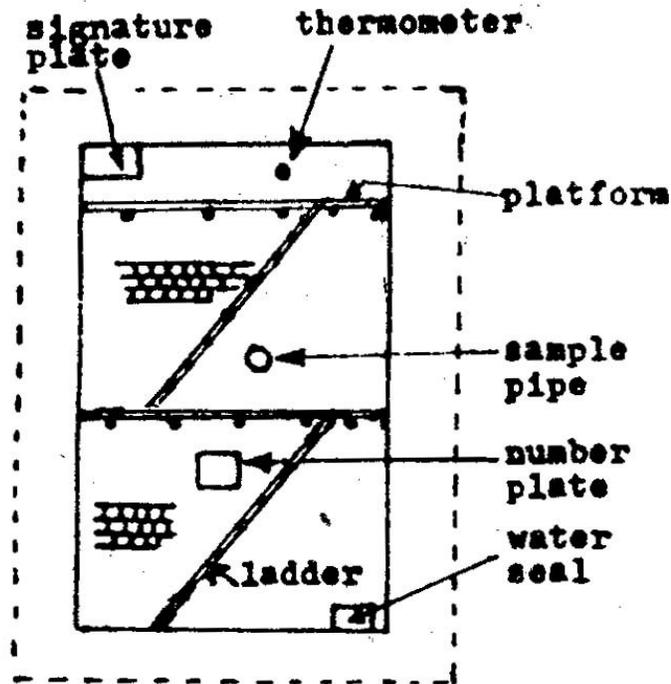
Permanent Stopping of brick in cement or lime are constructed out by of the temporary stoppings after a lapse of nearly 48 hours. A permanent stopping is the last step to seal off an area and the work should be reliable. The sites of permanent stoppings are selected at places free from cracks and having the minimum cross-section. The stopping should extend well into the floor, sides and roof-intact up to the stone in the roof-and for this purpose the cutting should be by miner's picks without the use of explosive which may cause cracks leading to leakage. The thickness of the stopping is nearly 1 m near the roof and it increases by 15 cm for every 3 m of height .In some mines like Jealgora stoppings had toe constructed in roadways 7 m high and in such roadways bottom 3 m section would be 1.30 m thick, the next 3 m section 1.15 m thick and the rest 1 m near the roof 1 m thick, Special attention. Should be paid to leying of the stopping against the roof as it is a comparatively difficult task, specially under restricted conditions of ventilation. The offset, if any, should be on the fire side so that the outbye side presents smooth surface which can be plastered and whitewashed for easy detection of cracks. In thick seams some time should be allowed for the brick construction to settle before the final jamming of the stopping against the roof, since the brick wall tends to shrink when the mortar is wet.

A fire stopping should have the following fittings:

- 1) Water gauge,
- 2) Thermometer,
- 3) A sampling pipe, 18 mm dia, with a valve for collecting samples of air from behind the stopping. The sampling pipe should pass through the temporary stopping and should extend about 3 m beyond it towards the fire side. One design of sampling pipe consists of a 5 cm dia. Pipe, 1.5 m long, grouted in the stopping and provided at its out bye end with a socket which, takes a brass plug; to the brass plug is fitted a 6 mm dia. Copper tube in 2 m lengths screwed together; the copper tube extends in bye the stopping to a minimum of 4.5 m and is supported on a brick pillar. (Fig. 4.2)

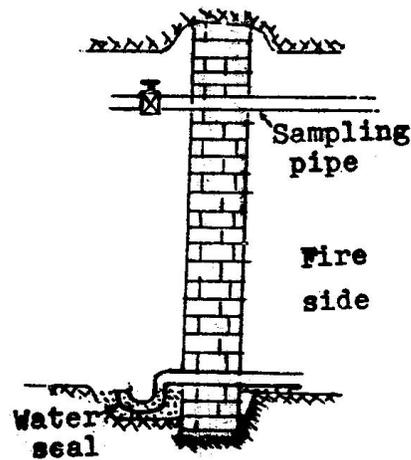


- 4) 50 mm dia.m.s. pipe with plug for recording temperature of the atmosphere behind the stopping.
- 5) Water seal at the floor level for drainage of water. A water seal consists of a piece of pipe built into the brick work at flow level with a bend at its out bye end which dips into the water contained in a small reservoir. The reservoir may be a ditch cut in the floor or a small brick work tank. The pipe is sometimes provided with a spring-loaded valve. When sufficient water accumulates behind the stopping, the valve open and allows the water to flow out bye but as soon as water is drained out, the valve closes under action of the spring. As the end of the pipe remains always under water, air cannot leak in.



Fire stopping in a thick seam.

- 6) A number plate giving the reference number of the stopping.
- 7) A signature board for the overman to put his signature and date after inspection of the stopping. If the stopping is high such board should be at the top and ladderways or platforms should be arranged zigzag so that all parts of the stoppings can be easily inspected by the overman as he travels to put his signature on the board.



Position of a sampling pipe in a stopping:

Atmosphere behind a stopping is still and the gases do not diffuse. The heavier gases like CO_2 settle to the floor level and the lighter gases like methane remain at the higher level. To get an air sample representative of the conditions behind the stopping, the sampling pipe should not be near the floor, nor near the roof but it should be preferably above the floor level at a height between $\frac{1}{2}$ and $\frac{3}{4}$ th the stopping height. Widthwise, it should be at mid width of the stopping. It should extend at least 3 m inside the stopping and to prevent its bending, should be supported on a brick pillar or a wooden prop.

If there is any leakage of air through the stopping, it is noticed by black streaks indicating deposit of soot or smoke at the cracks. Stoppings should always be kept whitewashed on easy detection of such cracks. Smoke indication of leakage may be available from smell. Increase of temperature behind the stopping indicates leakage of air into the sealed off area. In some cases there may be a hissing sound at the cracks if the leakage is heavy.

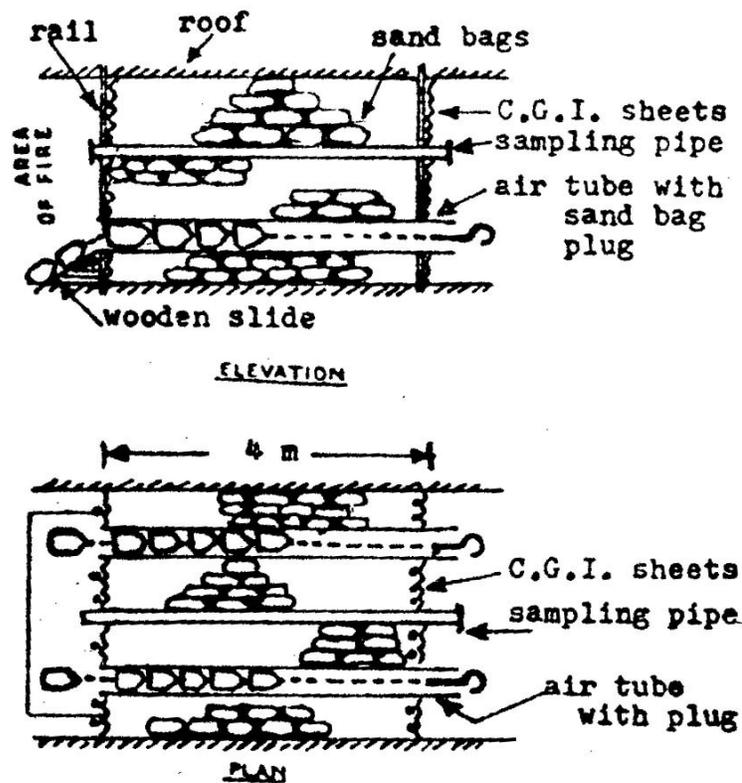
In a gassy mine, the construction of temporary stoppings stops air supply to the fire site but this results in gradual diminution of oxygen percentage from the air trapped behind the temporary stopping as the fire continues to burn. At the same time, the percentage of CH_4 issuing from the strata goes on increasing. These conditions create gas-air mixture which is potentially explosive and there is possibility of gas explosion within 24-48 hours after sealing the area by temporary stoppings which are not explosion-proof and are blown out by the explosion when one takes place. The construction of permanent stoppings to follow temporary stoppings is therefore, not recommended by some authorities who consider it advisable to construct temporary stoppings in gassy mines of robust construction and avoid the need for two sets of stoppings, temporary and permanent. The single set of stoppings is designed to combine the advantages of speedy construction and robustness of permanent stoppings.

8.9.ii) Sealing off a fire in a gassy coal mine (Cat.II & III)

The work of sealing a fire in gassy mines should be done by workers trained in the use of rescue apparatus and a rescue team with self-contained breathing apparatus should be kept in reserve.

At the stopping sites, selected after due consideration of the points stated earlier, robust stoppings, 4 m thick, of sand bags are constructed. During the construction the affected area is heavily stone dusted. Sufficiently large area near the fire is enclosed by the stoppings so that a large volume of air is trapped behind them. This ensures that when the stoppings are being constructed, there is enough air near the fire to prevent formation of explosive gas-air mixture and normal quantity of ventilating air should be allowed to reach the district by keeping the fan at the usual speed. During the construction of sand bag stoppings air supply to the fire area is maintained by providing two steel pipes, nearly 400 mm dia in them. At the time of final sealing of the stoppings the two steel pipes (air tubes) are closed by pulling a previous prepared sand bag plug with the aid of thin wire rope. To prevent the sand bags from slipping and falling over C.G.I sheets backed by steel rails are erected on the fire side of the stopping. Two holes, 400 mm dia are left in the C.G.I sheets for air tube, in addition a hole 50 mm dia. is left for the sampling pipe. The sand-bag stopping is reinforced on the out by side by C.G.I. sheets propped up by vertical rails or props.

A sampling pipe with valve has to be provided on the robust sand bag stopping. Final sealing of the stoppings, one on the intake side and the other on the return side is



Sand bag stopping.

effected simultaneously with the help of synchronised wrist watches.

During the process of sealing, the atmosphere near the stoppings should be tested frequently by CO detectors and flame safety lamps.

After the sealing all the workers engaged on the job should be withdrawn out of the mine. There is possibility of gas explosion within 24-48 hours of sealing and the mine conditions should be watched during the period. After the expiry of 48 hours air samples from behind the stoppings should be drawn and analysed on the surface. In deg. III gassy mines the stoppings should be reinforced on the out by side with brick stoppings of explosion proof design equipped with the fittings of permanent stoppings.

Samples of atmosphere from behind the stoppings should be collected at the following intervals:

- i) 48 hours after sealing8-hrs. Interval.
- j) When O₂ falls to 10% or low and methane rises to 16% or more24-hrs, interval.
- k) When O₂ falls to 5% or less and methane rises to 30% or more.....48-hrs. Interval or longer.

Air samples from behind the stoppings should be drawn during periods of low barometric pressure, such as between the hours 12 noon and 2 p.m. (DGMS Cir. 15 of 1961). The samples are collected in sampling bottles which are vacuum-sealed or in other bottles by water displacement.

Breathing at fire stoppings:

In a sealed off fire area as the oxygen of the trapped mine air is consumed its pressure becomes less than the atmospheric air in the mine and fresh air leaks into the fire area. This is called "breathing" . If the pressure inside the sealed off the area is positive due to emission of fire damp from the strata it will cause foul gases to leak out of the stoppings into the rest of the mine. Fluctuations of barometric pressure may also result in breathing. The leakage is usually small and cannot be prevented and it need not cause concern. If the stopping is whitewashed and the leakage is through small cracks in it , hair thin black lines of fine coal dust deposited on the cracks during leakage of air indicate the patches to be repaired.

In the case of a shallow mine the underground sealing is not effective if the fire area is connected to the surface through cracks. Depillared areas of the shallow mines are invariably so connected through surface cracks which have to be sealed by blanketing with inert material like earth or sand. The blanketing layer should be nearly 3 m thick. Earth blanketing is not as effective as sand since the earth develops cracks. Sand blanketing of surface over the goaves of shallow coal mines is noticeable in many parts of Jharia coal field where the inadequate attempts at sealing have not completely quenched the fires that have viewed through surface breathing and have gone beyond control.

A novel method of sealing an underground fire from the surface was adopted successfully at Kurasia Colliery (M.P.) in 1961. The colliery had underground workings in practically flat seam and the entrance was through adits. Part of the mine was worked by open cast mining with the help of heavy earth moving. Machinery. When a fire broke out in the underground mines

(depth 15-60m), it was decided to quench it from the surface. For this purpose the underground roadways were correctly correlated on the surface and 200 mm dia .boreholes, 600 mm apart were drilled from the surface with the help of well hole drills to join with the underground galleries. Each gallery which was selected for construction of fire stopping, received nearly 21 bore holes 7 in each row across the width of the gallery (4.8m). The number of holes depended upon the height of the gallery. Stone chips of +10 mm –60 size were dropped through the holes to fill up the gallery upto the roof. Liquid cement mortar was then injected down the hole at a high pressure. The stone chips and the liquid cement mortar, when consolidated, resulted into a good seal against the fire.

8.9.iii) Sealing the shaft:

If the shaft mouth has to be sealed to prevent entry of air into the mine on fire, the seal has to be built below the connection of the shaft with the surface fan drift. Holes are made in the shaft wall for placing steel rails. Over the steel rails are placed C.G.I. sheets and a layer of concrete about 1 m thick.

Flooding the mine with water or inter gas

An underground fire may be quenched by pumping water into the mine through shaft or bore holes if a river or water tank is nearby and has sufficient water. The gas explosion at chinakuri Colliery in 1958 had resulted into a fire which was quenched by pumping Damodar River water into the mine and not by underground methods of sealing. The method is very effective if attempt to seal the fire by underground stoppings is fraught with risk of gas explosions. If the explosion damages the headgear, the winding pulley and the winding arrangements , thereby making it impossible to go down the mine, the fire has to be tackled by flooding from the surface or by sealing the mouth of the shaft. Water cools down the underground strata faster than in the case of a fire quenched by fire stoppings and reopening of the sealed area need not wait for long. The method can however be adopted if the water can be retained in the mine and is resorted to only in the following cases:

- (1) Sufficiency of water near the mine.
- (2) Out break of fire on the dip side of the mine.
- (3) Non-existence of goaves on the dip side connected to other mines.
- (4) Non-existence of connecting galleries/drifts to other seams .or other mines.
- (5) Sufficient thickness of barrier against the mine on the dip side to withstand water pressure.
- (6) No possibility of dangers from land sides. In shallow mines, here is danger from the land slides if the mine is flooded.

Quenching a fire by flushing with nitrogen gas was practised in some mines in India, e.g. at Ramagundam, Kenda group, etc. For small requirements, the gas can be obtained in gas cylinders. A large demand required use of tankers for transport of liquid nitrogen just like the familiar liquid oxygen tankers which are well insulated to reduce evaporation of gas during transport. In Jharia field such liquid nitrogen can be obtained from Sindri Fertiliser Plant. If the

demand for liquid nitrogen is excessive, it is advisable to install nitrogen evaporating plant at the mine site. For example, at Fernhill colliery in U.K. where an underground fire sealed by fire stoppings could not be effectively controlled, a nitrogen evaporating plant was erected underground and the inert nitrogen gas was fed to the fire zone. That extinguished the fire. This was done nearly 3 decades ago.

In Jharia field fire near Lodna and other fire areas was prevented from spreading further by installing near the fire area nitrogen producing machine. Such machine separated gaseous nitrogen from gaseous oxygen of the atmospheric air (in the gaseous form) and the nitrogen was fed to the fire area. As fire is near the surface, breathing of air to the fire area was hindering fire quenching operations and the machine could be used only to contain the fire.

In recent years (in 1989) fire in a goaf of a coal mine in north eastern France was quenched by a novel method which involved sealing of a roadway from a remote location through a specially drilled 85-m long bore hole which was used from injection of expanding Mariflex foam resin. The method was adopted after injection nitrogen gas proved ineffective. Mariflex has a swell factor of more than $\times 20$.

In some mines pipelines for the injection of nitrogen are installed as a preparatory measure and they are linked to a surface supply system of nitrogen gas. Such was the case for the workings of Henri seam in Marienau field in North Eastern France where fire took in 1989.

Reversal of Ventilation after fire

If a fire takes place in or near the DC shaft, smoke and fumes are carried by the ventilation current in by to the working faces and endanger the men working at the faces. The smoke and fumes will soon travel to the main return and make the return airway unsafe as an escape route.

Reversal of ventilation in Degree-II and , Degree-III gassy mines, is a major decision which only the mines manager should take after the occurrence of a fire or explosion. The reversal of ventilation may be advantageous if a fire is in the DC shaft or in its vicinity in the main intake airway. The reversal prevents the smoke and fumes from reaching the working faces where majority of the workers may be present. The reversal results in throwing open the separation doors between the DC and UC shafts and also other ventilation doors between the intake and return airways. This causes short circuiting of ventilation and steps should be taken to see that the separation doors and ventilation doors are kept closed. The nearest ventilation stopping in by of the fire side should be broken to short-circuit air after reversal. If the mine is ventilated by a forcing fan, the reversal results in to exhaust ventilation and in Degree-II and Degree-III gassy mines, reversal may cause movement of large bodies of gas from goaves and old workings into the main intake airway and from there, over the fire with consequent risk of explosion. In a deep mine ventilated by an axial flow fan the latter may not be able to develop sufficient water gauge after reversal to contract the N.V.P. in winter reversal would not prove effective.

8.3 SUMMARY:

Spontaneous heating, Friction, Electricity, Blasting, Explosions are different causes of mine Fires. Sp heating is playing a vital role in mine fires.

Spontaneous heating:

It is self heating of coal or carbonaceous material resulting eventually in its ignition without the application of external heat or on to oxidation of the coal.

The most important theories of sp heating that had been advanced are:

- 1) Bacterial theory
- 2) Pyrite theory
- 3) Phenol theory
- 4) Coal-oxygen complex theory

There are different factors contributing sp heating, like presence of Iron Pyrites, area of the surface coal, nature of the coal, Depth of the seam, thickness of the seam, Geological Disturbances, time factor, petrographic composition. Different preventive measures are then to control sp heating. They are development of required seams, panels. Controlled winning methods, roof control. Sufficient ventilation, Inspecting the affected areas.

There are different stages of spontaneous combustion of coal, they are incubation period, indication period, open fire.

8.4 ASSESSMENT:

8.4.1 Short Answer Type Questions:

- 1) List Types of fires?
- 2) Define Spontaneous Heating?
- 3) List causes of fires?
- 4) List the signs of spontaneous heating?

8.4.6 Essay Type Questions:

- 1) List the factors for developing spontaneous heating?
- 2) Explain preventive measures of spontaneous heating?
- 3) Explain different methods of dealing with fires?
- 4) Explain the method of sealing off fire gassy coal mines of II & IIIS Degree.

8.4.7 Objective Type Question:

- 1) What type of reaction the spontaneous heating is _____.

a) Endothermic reaction	b) Exothermic reaction
c) both the reactions	d) None of the above
- 2) The following thing causes spontaneous heating

[b]

- a) FeS_2 b) CaS_2 c) NaS_2 d) None of the above [a]
- 3) The following is not the factors for spontaneous heating.
a) Oxygen b) good rank coal c) surface area d) ash [d]
- 4) The following is not the by product of spontaneous heating
a) CO_2 b) CO c) Heat d) C [d]
- 5) The theories of spontaneous heating is/are_____
- a) Bacterial Theory b) Pyrite Theory
c) Phenol Theory d) all the above [d]

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