Mine Explosions

Mine Hazards, Rescue, and Recovery

Intro:

Explosion:

An explosion is a

- **sudden combustion process** of great intensity
- accompanied by release of **large quantities of heat energy** and
- in which the **original gas or solid substance** (like coal dust) is **converted instantaneously into gaseous products**

Intro:

Explosions in coal mines are of:

1) **Firedamp**

Firedamp has been the cause of most of the explosions in coal mines

2) **Coal dust**

Explosions of coal dust alone have been comparatively rare though they have been initiated by firedamp explosions in a number of cases

3) **Water gas**

Water gas explosions are rare

Firedamp explosion:

- Gas mixture: Methane (CH_4) + Air (O_2)

- An **explosive mixture of gases** is one which, when **once ignited** will **allow the flame to be self-propagated throughout the mixture**, **independent of and away from, the source of ignition**

Firedamp explosion:

- Presence of firedamp in air between **5.4 and 14.8%** forms an explosive mixture
- The **maximum explosive violence** is produced when the explosive mixture contains about **9%** of firedamp
- **All the low mixtures of methane burn in air producing a bluish flame**

Firedamp explosion:

- **Laboratory experiments** have proven that by suddenly compressing the gas-air mixture,
    - mixtures containing **as low as 2% and as high as 75% firedamp**,
    - can be ignited and made explosive as **both the temperature and pressure are raised simultaneously**

Firedamp explosion:

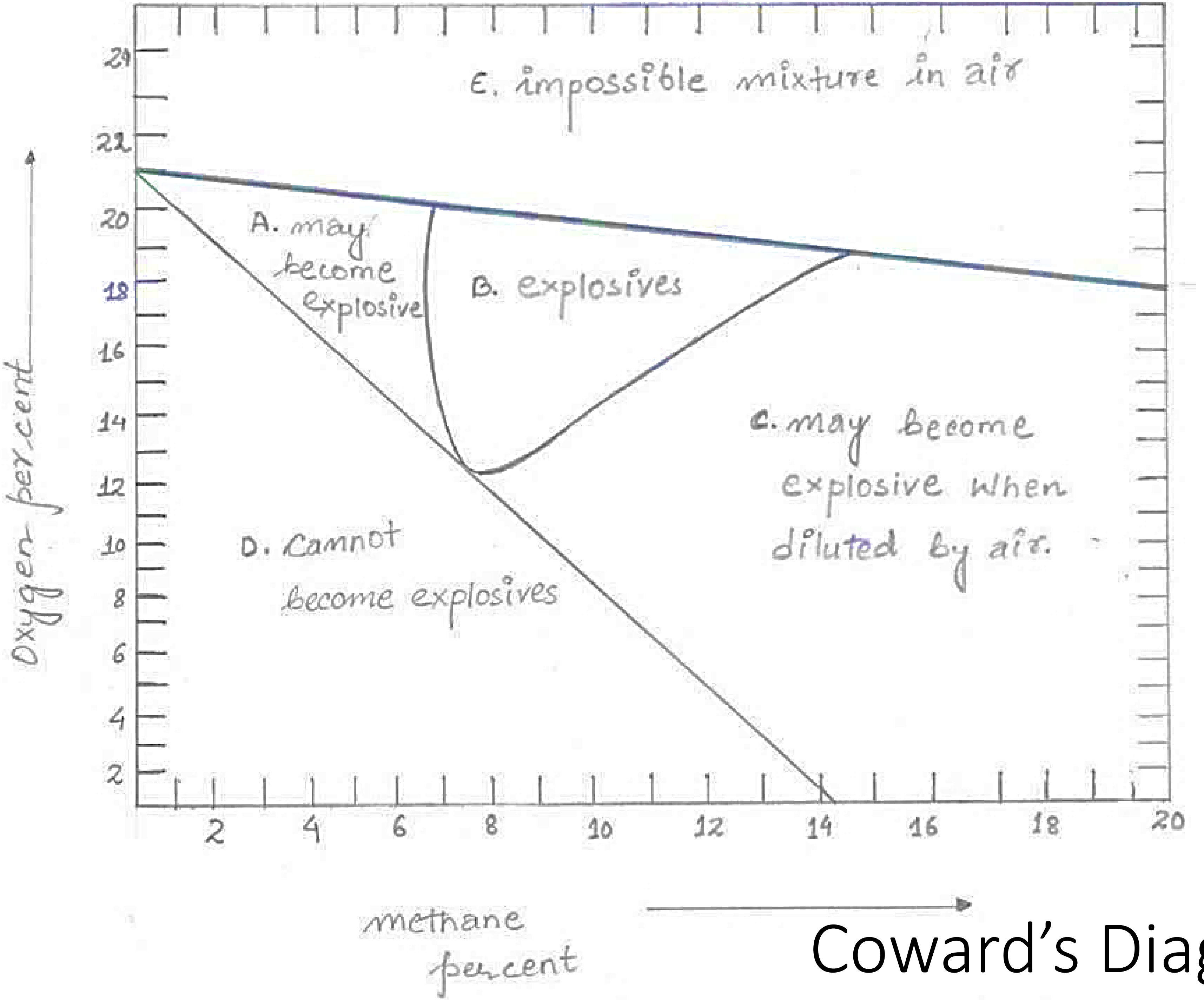
- The **lower limit of explosibility** with which a miner is primarily concerned, remains practically **unaffected by presence of black damp** as may normally be found in mines

- The percentage of **blackdamp exceeds about 35**, the atmosphere become **non-explosive irrespective of any percentage of fire damp**

Firedamp explosion: Coward’s Diagram

- Coward’s Diagram diagram helps us to find the **flammability/explosibility of methane- air mixtures** as the composition changes

- Developed by scientist **H. F. Coward in 1928**



Coward’s Diagram

Firedamp explosion: Coward's Diagram

Some of the salient points to be observed from the explosibility curve of methane are:

1. All mixtures lying within the triangular area B, are in themselves explosive.
   a. **Lower limit of explosibility remains almost constant at about 5.4 for all percentages of oxygen down to about 12%.**
   b. **The higher limit of explosibility gradually decreases from 14.8% with decreasing percentage of oxygen.**
   c. **Firedamp is not explosive** when the **percentage of oxygen is less than 12.**

Firedamp explosion: Coward's Diagram

Some of the salient points to be observed from the explosibility curve of methane are:

2. In region A, **the mixture is not Explosive**. However, it **may become explosive if further methane is added** to it. This is possible, when that particular portion of the mine is **sealed off and continuous emission and accumulation of methane in that area**.
3. All mixtures lying in the **area C contain too much methane to explode** but they **will form explosive mixtures when mixed with the right amount of air**.

Firedamp explosion: Coward's Diagram

Some of the salient points to be observed from the explosibility curve of methane are:

4. All mixtures lying in the **area D are neither explosive nor capable of forming explosive mixtures with air**.

5. The region E depicts the **CH_4-O_2 mixtures impossible** to form when **air is the source of O_2**.

Firedamp explosion: Ignition temperature

- The ignition temperature of methane is **650 to 750° C**

- The ignition temperature can be influenced by
  - **the presence of various impurities in methane and**
  - **the pressure of the gas-mixture**

Firedamp explosion: lag on ignition

- 'Lag on ignition' is defined as the time interval between the exposure of "$\mathbf{CH_4\text{-}O_2}$" to an igniting source to the appearance of flame

  - at **650° C the delay is ten seconds**

  - at **1000°C it falls to one second**

- The **presence of hydrogen and other combustible gases** in methane reduces the delay on ignition, e.g., the presence of 30% hydrogen in methane eliminates the delay completely

Firedamp explosion: Sources

- Methane is **emitted mainly from coal seams and associated strata** in an underground mine

Firedamp explosion: Causes of explosion/ignition

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

- Carelessness of miners
- Use of damaged flame safety lamps and their improper handling
- Blasting
- Mine fires
- Friction
- Electric sparks
- Static charges

Firedamp explosion: Prevention of explosion

- **No practical measures exist for arresting firedamp explosions** in coal mines.
- Only **preventive measures against this hazard can be adopted**:

1) **Measures against accumulation** of dangerous firedamp mixtures in mine workings from the beginning.
2) **Measures against ignition** of firedamp mixtures
3) **Control of Firedamp Emission**

Firedamp explosion: Prevention of explosion

1) **Measures against accumulation** of dangerous firedamp mixtures in mine workings from the beginning

i. The mine should be **mechanically ventilated**. A reserve or standby main fan having an independent drive and power circuit should be provided.

ii. The entire mine should be **ventilated by the exhaust ventilation method**.

Firedamp explosion: Prevention of explosion

1) **Measures against accumulation** of dangerous firedamp mixtures in mine workings from the beginning

iii. The mine ventilation system should be planned so that **simple effective and reliable ventilation** of all workings is assured.

iv. Air-leakage should a minimum.

Firedamp explosion: Prevention of explosion

1) **Measures against accumulation** of dangerous firedamp mixtures in mine workings from the beginning

v. The ventilation of development headings should be done by utilizing the mine ventilating pressure as far as practicable. **If auxiliary fans are required to be used, they should be installed and located in such a manner that recirculation of air is eliminated**.

Firedamp explosion: Prevention of explosion

1) **Measures against accumulation** of dangerous firedamp mixtures in mine workings from the beginning

vi. A particularly **high standard of unit ventilation should be maintained in districts liable to outbursts**.

vii. Air currents and methane emission should be controlled by **systemic measurement of air quantities and their methane concentration**

Firedamp explosion: Prevention of explosion

2) Measures against ignition of firedamp mixtures

i. All persons should be **prohibited from carrying smoking articles, matches or other spark or flame-making devices**.

ii. Only **approved types of flame and electric safety lamps should be used**. The safety lamps should be properly maintained and carefully used.

Firedamp explosion: Prevention of explosion

2) Measures against ignition of firedamp mixtures

iii. Only **certified flameproof and intrinsically-safe apparatus should be used**. The apparatus should be properly installed, protected, operated, and maintained.

iv. The production of **excessive frictional heat with conveyors, brakes, and bearings should be avoided** by good installation and proper maintenance.

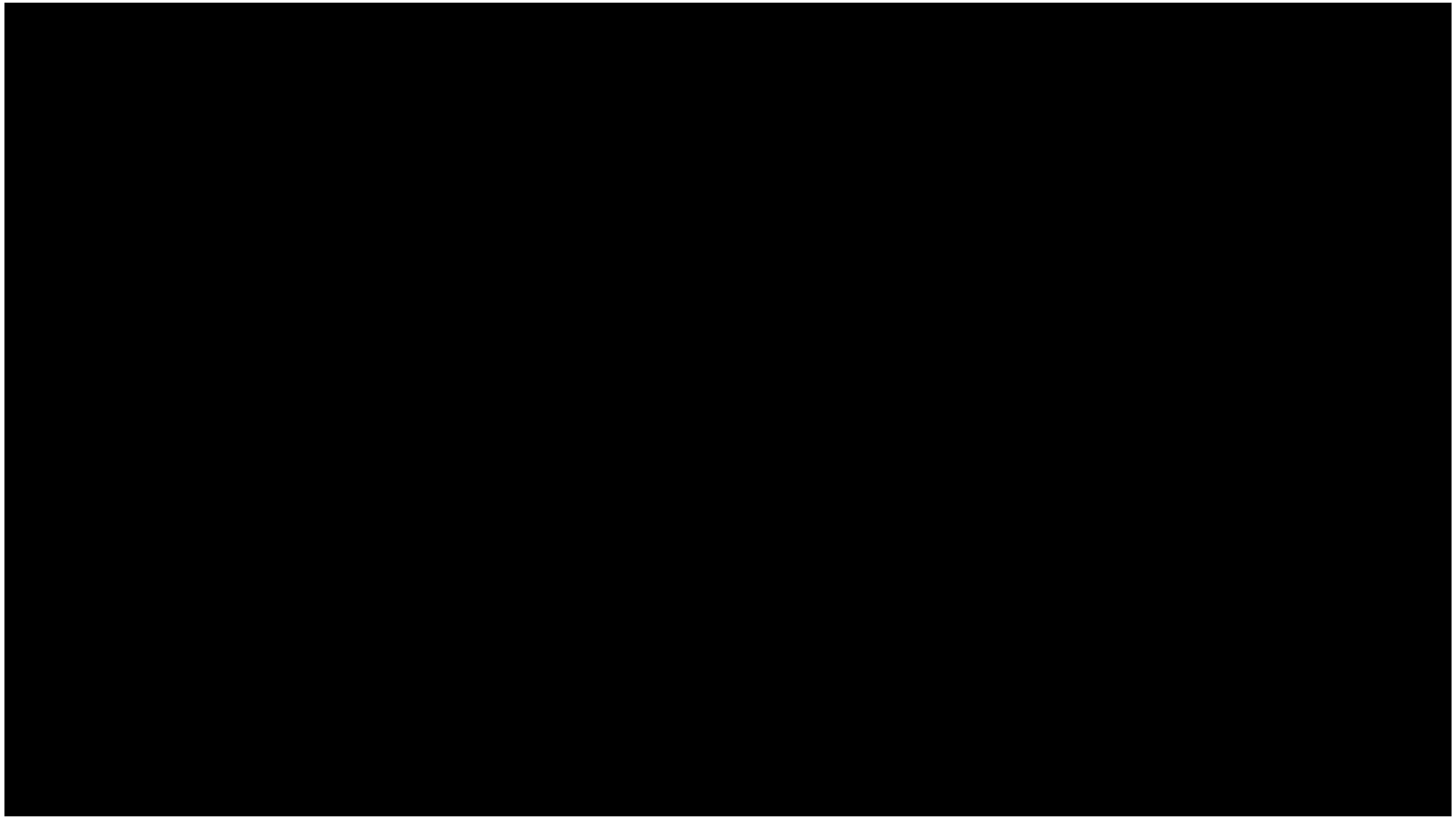
v. Spontaneous heating of coal should be controlled by proper planning of mine development as well as coal extraction, good ventilation system, and inspection.

Firedamp explosion: Prevention of explosion

3) Control of Firedamp Emission

In mines where high emissions of firedamp are expected, it is prudent **to drain the strata of the gas by means of boreholes** at the beginning (methane drainage) than wait until the methane content of the return and the general body of air poses a serious problem.

Coal dust explosion:



Coal dust explosion:

- It been established by experiments and on the basis of studies of a number of explosions that coal dust, when **suspended in the air as a cloud**, is capable of bursting into an explosion and propagate it, even in the absence of firedamp

Coal dust explosion:

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

- The quantity amounts to **30 to 40 g/m³ of space**.

Coal dust explosion:

- Once the coal dust explosion starts, its **propagation needs very small quantity of the dust**, only **1 g/m³ of space**.
  - **This quantity is so small that it is impossible to keep a mine free from such small accumulations**.
  - For this reason, w**hen a coal dust explosion takes place, it travels to practically all parts of the mine**.

Coal dust explosion:

- For a coal dust explosion to take place the **dust must first be raised into air in the form of a cloud**, as already stated, and **then ignited by a source of heat of sufficient intensity**

- Such circumstances generally exist **after a firedamp explosion**

- This however, **does not imply that all firedamp explosions are followed by coal dust explosions**

Coal dust explosion: Ignition temperature

- The lowest temperature at which a fine dry coal dust cloud can be ignited and can cause the flame to travel throughout the dust-air mixture is **700 to 800°C**

Coal dust explosion: explosibility of a coal dust

- The explosibility/inflammability of a coal dust may be defined as **its ability to spread away the flame from the source of ignition**

- Some coal dusts are more inflammable than others.
  - The **lower limit of explosivity of coal dust is 1 g/m^3 of space** but the **higher limit** is quite high and for bituminous coals it is **above 2000 g/m^3 of space**

Coal dust explosion: explosibility of a coal dust

- The **inflammability of a coal dust is dependent upon the following factors**:
  1) Percentage of volatile matter
  2) Fineness of particles
  3) Percentage of inert or incombustible matter
  4) Presence of moisture
  5) Presence of fire damp
  6) Nature and intensity of ignition source,
  7) Age of the dust,
  8) Condition of dust distribution.

Coal dust explosion: explosibility of a coal dust

- Percentage of volatile matter: **The inflammability increases with the V. M. content.** It is observed that coal containing less than 13% of V. M. calculated on dry ash-free basis, is not likely to propagate flame.

- Fineness of coal dust particles: **Finer the coal dust, greater is its inflammability**. The finest dust is most dangerous.

Coal dust explosion: explosibility of a coal dust

- Percentage of incombustible matter: **The incombustible matters present in coal dust are moisture and the inherent ash** which **decrease the inflammability of coal dust**. In a mixture of a coal and rock dust in a mine the incombustible matter absorbs some of the heat of the igniting source so that the temperature of the combustible portion does not reach the igniting temperature and flame cannot be propagated. this is the principle behind "stone dusting" in coal mines.

Coal dust explosion: explosibility of a coal dust

- Presence of moisture: **External moisture added to coal dust reduces its inflammability** and if the moisture is in sufficient quantity, it binds the dust particles together there by preventing them from rising in the air as a cloud. The quantity of moisture that would ensure non propagation of flame by coal dust is however high, at least 1/30th of the total mixture. The dust in contact with so much moisture would be in the form of a thin paste which is rarely present in a mine, except at a few local places.

Coal dust explosion: explosibility of a coal dust

- Presence of fire damp: **The inflammability of coal dust increases almost directly in proportion to the percentage of firedamp present in the atmosphere.** For every 1% firedamp 10 to 14 % additional stone dust is required for efficient stone dusting.

- Nature and intensity of ignition source: These factors influence the inflammability of coal dust. **Explosions initiated by high temperature sources develop the explosion faster and cause more damage.**

Coal dust explosion: explosibility of a coal dust

- Age of coal dust: **Weathered coal dusts are more inflammable as they contain oxygen loosely combined with the coal substance.**

- The varying conditions of dust distribution and propagation of the explosion also affect the course of dust explosions. **The least dangerous condition of the dust generally is on the floor and sides; the most dangerous position is on the roof and on the bars of the timber props.**

Coal dust explosion: Causes/source of ignition

- Naked flames
- Blasting
- Mine fires
- Friction
- Electric sparks
- Firedamp explosion

Coal dust explosion: Preventive measures

A coal dust explosion can be prevented by

1) **Reducing the formation of coal dust** at the working faces, haulage roads and elsewhere.
2) **Preventing its spread**.

A coal dust explosion and propagation can be prevented by

3) **Rendering coal dust harmless** by wetting it with water or mixing with inert stone dust.

Propagation of a coal dust explosion can be prevented by

4) **Provision of stone dust barriers or water barriers**.

Coal dust explosion: Preventive measures

1. & 2. **Formation and spread of coal dust** can be reduced in the following ways:

A. At the face:

i. **By water infusion:** At the longwall face holes are drilled at an angle of about 45° to the face and water under high pressure is injected into them till a thin film of water is visible at the coal face. Water infusion has the further advantage of rendering the coal easier for ploughing and sharing.

Coal dust explosion: Preventive measures

1. & 2. **Formation and spread of coal dust** can be reduced in the following ways:

A. At the face:

ii. By use of water sprays on the coal cutting machine picks and shearer picks.

iii. By the **use of sharp picks** on the coal cutting machines and the shearers. Blunt picks produce more coal dust.

Coal dust explosion: Preventive measures

1. & 2. **Formation and spread of coal dust** can be reduced in the following ways:

A. At the face:

iv. Giving cut by coal cutting machine in a soft stone band or shale band if one is present at the coal face to generate stone dust to reduce the chances of coal dust explosion.

v. By **selecting right type of explosives and by proper control of shot firing** so that the blasting operations produce less dust.

Coal dust explosion: Preventive measures

1. & 2. **Formation and spread of coal dust** can be reduced in the following ways:

B. During transport of coal:

i. **Coal tubs and mine cars should be spillage-proof.**
ii. **Haulage track should be well laid to prevent derailments**.
iii. **Belt conveyors should be properly aligned** and so installed as to avoid spillage. The fall of coal from the conveyor or the mine cars or tubs should be minimum.

Coal dust explosion: Preventive measures

1. & 2. **Formation and spread of coal dust** can be reduced in the following ways:

B. During transport of coal:

iv. **Water spraying at loading points, transfer points and over the loaded coal tubs** helps in reducing the distribution of coal dust.

v. **Low air velocities of the ventilating air current at the face and on the haulage roads** are a further contributory factor for reducing coal dust in the air.

Coal dust explosion: Preventive measures

1. & 2. **Formation and spread of coal dust** can be reduced in the following ways:

B. During transport of coal:

vi. Dust at transfer points may be collected by the use of dust extractors.
vii. Loading of skips should be arranged in the upcast shaft.
viii. Surface screening plant and tipplers should be at least 50 m away from the intake shaft. Use of water sprays at the tipplers is recommended.

Coal dust explosion: Preventive measures against explosion/propagation

3. **Rendering coal dust harmless** by wetting it with water or mixing with inert stone dust:

A. **Wetting the coal dust:**

- **Water spray-** roof, sides and floor
  - Tends to make the **floor slippery**
  - Introduction of water in the mine has the disadvantage of **increasing the humidity**
  - **Sufficient water may not be available**
    - water may be used **only for local application**, e. g. at transfer points, or on loaded coal tubs

Coal dust explosion: Preventive measures against explosion/propagation

3. **Rendering coal dust harmless** by wetting it with water or mixing with inert stone dust:

B. **Application of stone dust:**

- The **stone dust** mixed with coal dust, has the effect of **absorbing the heat** that would **otherwise ignite the coal dust cloud** and therefore the stone dust **prevents coals dust from reaching the ignition point**

Coal dust explosion: Preventive measures against explosion/propagation

Coal dust explosion: Preventive measures against explosion/propagation

3. **Rendering coal dust harmless** by wetting it with water or mixing with inert stone dust:

B. **Application of stone dust:**

Advantages:

- **Easily dispersible** to form a cloud in the air when disturbed
- Easily **available in large quantities** and easily grindable
- Not **injurious to health-** Siliceous dust should be avoided
- Preferably **white in color**

Coal dust explosion: Preventive measures against explosion/propagation

3. **Rendering coal dust harmless** by wetting it with water or mixing with inert stone dust:

B. **Application of stone dust:**

- Dust of **shale, limestone or gypsum** is generally recommended for use.
- The **percentage of incombustible dust** in the coal/ stone dust sample in a mine should be **50 to 60 %** for the stone dust to be effective in preventing propagation of flame.

Coal dust explosion: Preventive measures against explosion/propagation

3. **Rendering coal dust harmless** by wetting it with water or mixing with inert stone dust:

B. **Application of stone dust:**

- **Stone dusting** of underground road ways should be **carried out at regular intervals** so that the top layer is of stone dust.
- **Samples of coal dust in the mine treated with stone dust** should be taken at **regular intervals**, once a week, and **analyzed** to know the content of stone dust.
- **Stone dusting and wetting of coal dust by water cannot go together.**

Coal dust explosion: Preventive measures against propagation

4. Provision of stone dust barriers or water barriers:

- A stone dust barrier consists of **shelves placed side by side**
- Each **shelf consists of planks** placed on above the other and **loaded with stone dust**
- These are **placed on supports in the main roadways** of an underground mine
- Designed in such a manner that the **planks collapse with the shock of an explosion**

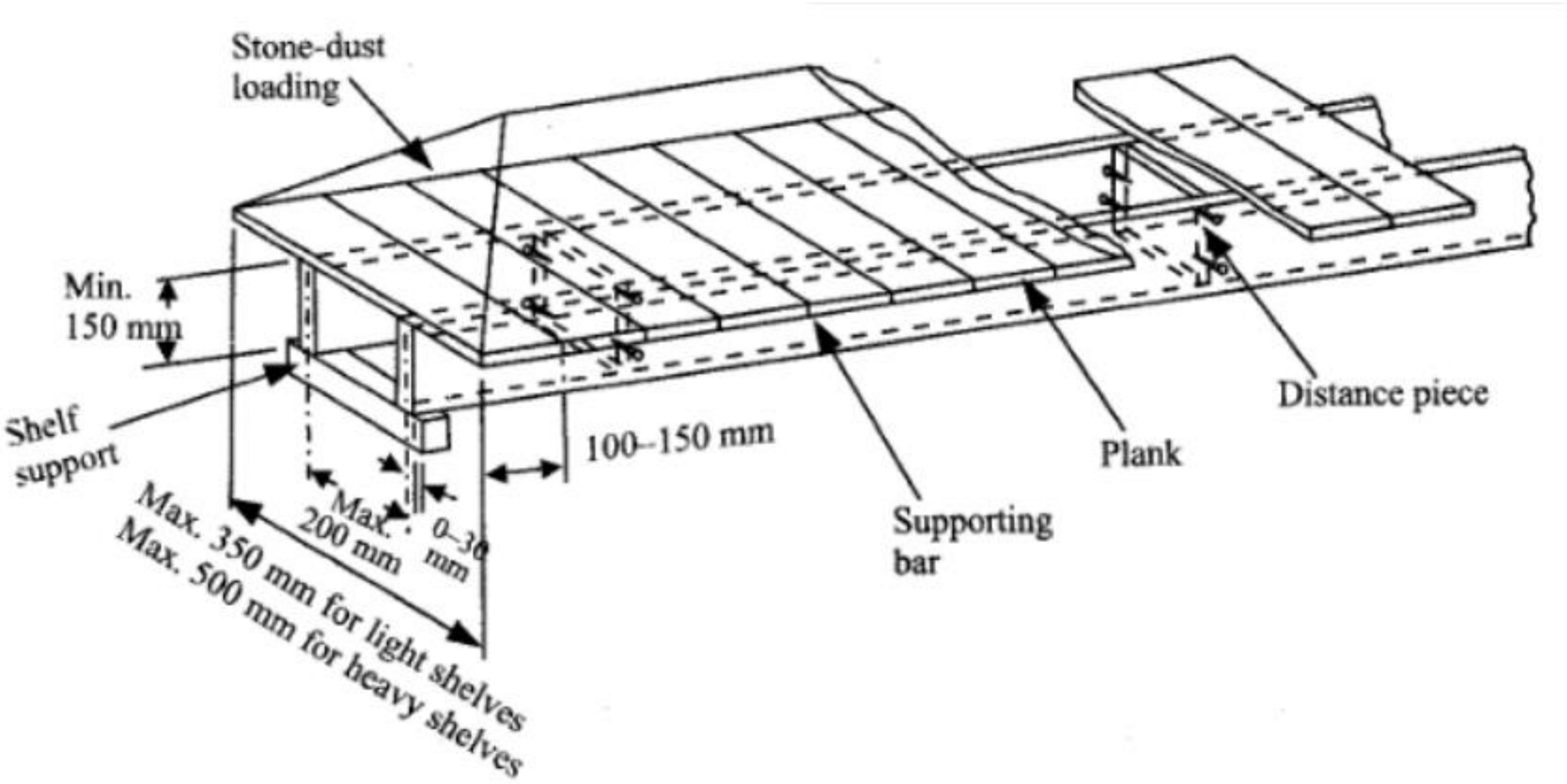
Coal dust explosion: Preventive measures against propagation

4. **Provision of stone dust barriers or water barriers:**

- **Causing the stone dust to disperse in air and form a thick stone dust cloud** in the path of the oncoming explosion flame
- The **stone dust cloud smothers the flame** and prevents ignition and explosion of the coal dust
- Stone dust barriers have to be provided in addition to the normal measures like coal dust wetting or stone dusting adopted in a coal mine to counter the danger of coal dust

Coal dust explosion: Preventive measures against propagation

4. Provision of stone dust barriers or water barriers:



Polish Shelf

Coal dust explosion: Preventive measures against propagation

4. **Provision of stone dust barriers or water barriers:**

- Design of stone dust barriers:
  - The D.G.M.S. Circulars recommend adoption of Polish type of stone dust barriers.
  - In this type of barrier, the stone dust rests on planks which run longitudinally in the road-way and whose length equals the width of the shelves.
  - These planks rest on a rigid frame, the two main members of which are at least 150mm in depth and rest on their edges on two fixed rigid brackets.

Coal dust explosion: Preventive measures against propagation

4. **Provision of stone dust barriers or water barriers:**

- Design of stone dust barriers:
  - Neither the frame, nor the planks are fastened either to each other or to the fixed brackets.
  - To ensure it collapses in the event of an explosion and the stone dust cloud smothers the flame and prevents ignition and explosion of the coal dust.

Coal dust explosion: Preventive measures against propagation

4. Provision of stone dust barriers or water barriers:

- Design of stone dust barriers:
  - According to the **loading of the shelves and the total quantity of stone dust on the shelves**, the barriers may either be as:

    1. **Light, also called primary or first barrier**
    2. **Heavy, also called secondary or second barrier**

Coal dust explosion: Preventive measures against propagation

4. Provision of stone dust barriers or water barriers:

- Design of stone dust barriers: **Light/ primary/ first barrier**

  - Light type of barriers is intended for use **nearest to a possible point of ignition**.
  - They consist of **light loaded shelves not more than 350 mm in width**.

Coal dust explosion: Preventive measures against propagation

4. **Provision of stone dust barriers or water barriers:**

- Design of stone dust barriers: **Heavy/ secondary/ second barrier**

  - Heavy type of barriers is intended for use **further from the possible site of explosion.**
  - They **contain more dust** because the **greater distance will give the explosion the opportunity to develop greater violence** which will then be difficult to stop. The amount of dust in a heavy barrier should be adequate to stop such an explosion.

Coal dust explosion: Preventive measures against propagation

4. Provision of stone dust barriers or water barriers:

Location of stone dust barriers: **B/P**

- It is sufficient to provide **a single heavy type barrier** sited at a sufficient distance from the face to ensure that there is **no likelihood of its being passed by the flame from a firedamp explosion originating at the face**.
- Such a barrier should be provided at a distance of **not less than 150m from the nearest working face and at not more than 400m from the farthest face.**

Coal dust explosion: Preventive measures against propagation

4. **Provision of stone dust barriers or water barriers:**

Location of stone dust barriers: **B/P**

- The **barriers shall be kept advanced to their new positions and when necessary**.
- To be effective, **the heavy barrier will have to be provided in all the entries to the district.**
- The **shelves of the barrier would ordinarily be included in about one pillar length**.
- The shelves should **not be positioned at a junction**.

Coal dust explosion: Preventive measures against propagation

4. Provision of stone dust barriers or water barriers:

Location of stone dust barriers: **L/W**

- In the longwall workings a barrier of **light type** should be installed in all longwall **gate conveyor roads within the range of 50-120 m from the nearest point of the face.**
- A **second barrier (heavy type)** should be placed further **outbye at 200-350 m from the face**.

Coal dust explosion: Preventive measures against propagation

4. Provision of stone dust barriers or water barriers:

Location of stone dust barriers: **Near Shaft Insets**

- **Heavy type of barriers should be sited in the roads adjacent to the shaft landings**

- **At a distance of 100m to 150 m from the landing**

- These barriers should as far as possible and so arranged that they are in the **middle of a straight stretch of road at least 200 m in length**