

## UNIT-X

### MINE EXPLOSIONS

#### 10.0 OBJECTIVES

- At the end of the chapter the student will be able to learn,
- Different types of explosions, causes and preventive measures of fire damp explosions.
- Causes and preventive measures of coal dust explosions.
- Method of treating coal dust
- The purpose of construction of stone dust barriers and their location and application and functions of Water Barrier.

#### 10.1 INTRODUCTION

An Explosion is a sudden combustion process of great intensity, which is accompanied by release of large quantities of heat energy and in which the original gas or solid coal substances are converted into gaseous products.

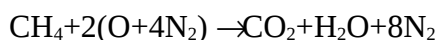
##### 10.1 Types of Explosions

1. Fire damp explosions (Where the ignition source is fire damp)
2. Coal-dust Explosions (Where the ignition source is coal dust)
3. Water-gas Explosions.(Where the source is red hot coke and water)

##### *Firedamp explosions*

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

The combustion and explosion takes place according to the equation



One volume of methane requires+ 2 volumes of O<sub>2</sub> →For its complete combustion process.

The Optimum or Stoichiometric mixture is formed at 9.5% of methane. Methane has flammable mixtures with air over a number of approximately 5 to 15%.

If CH<sub>4</sub> % is greater than 9.5% → Oxygen percentage will not be sufficient for its complete combustion.

If CH<sub>4</sub> % is less than 9.5 →Oxygen percentages will be excess for its complete combustion.

### I. Limits of flammability or flammable limits

The smallest percentage of combustible gas (methane air mixture) in air that will propagate an explosion is called the Lower limit. The highest concentration of methane air mixture that propagates an explosion called upper limit. These limits also called as explosability limits.

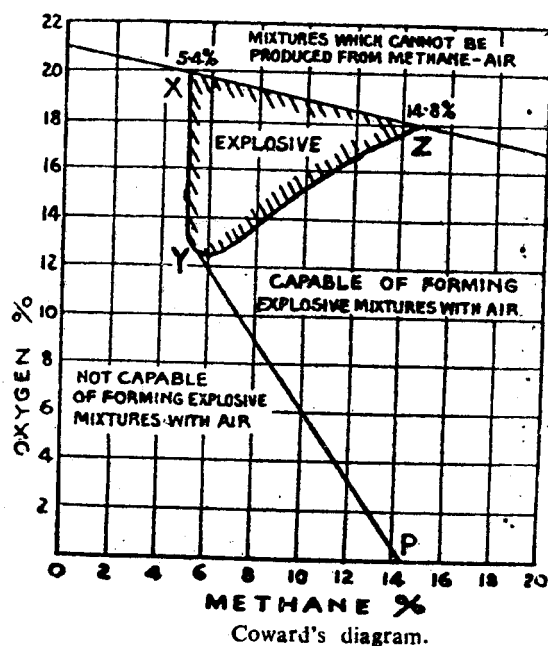
Lower Flammable Limit → 5% of  $\text{CH}_4$  for firedamp explosion. 33 gms/m<sup>3</sup> of coal dust concentration for coal dust explosion.

Upper Flammable Limit → 15% of  $\text{CH}_4$  for firedamp explosion. 100 gms/m<sup>3</sup> of coal dust concentration for coal dust explosion.

The limits of flammability are not the fundamental characteristics of the gas but depend on experimental condition they are influenced by.

- 1) Presence of other combustible and inert gases.
- 2) Temperature.
- 3) Pressure.
- 4) Intensity of Turbulence.
- 5) Diameter of experimental tube.
- 6) Direction of flame propagation.
- 7) Intensity of ignition source.
- 8) Presence of coal dust.

The pressure of other combustible gases like ethane, carbon monoxide, hydrogen etc., which have like methane lower and upper flammable limits also reduces the lower limit which can be determined by using the --- Chartelier Relation



$$\frac{100}{L} = \frac{P_1}{l_1} + \frac{P_2}{l_2} + \frac{P_3}{l_2} + \dots$$

Where  $P_1, P_2, P_3, \dots$  are percentages of component gases ( $P_1 + P_2 + P_3 + \dots = 100\%$ )

$l_1, l_2, l_3, \dots$  are their percentages of lower limits

The presence of inert gases have a damping effect on the flammability of methane air mixtures  $\text{CO}_2$  is more affective than  $\text{N}_2$

I. Ignition point or Ignition Temperature:

The ignition temperature of Flammable Fire Damp Air

Mixture PS  $\longrightarrow$   $650^\circ\text{C}$  to  $750^\circ\text{C}$

*The Ignition Temperature depends on following factors:*

1. Nature of source of Ignition (Flame, Spark etc.,)
2. Shape and size of roadway where ignition occurs
3. Methane content
4. Temperature of surrounding
5. Pressure
6.  $\text{O}_2$  concentration
7. Presence of other gases.
8. Temperature.

*Ignition Lag:*

If the ignition source is little above the ignition point certain time must be elapsed before it is ignited, this time is called "ignition lag".

Ignition Lag depends on

- i) Temperature
- ii) Pressure
- iii) Gas concentration
- iv) Presence of Other combustible gases.

It is found that

- (a) With 6.5 % of  $\text{CH}_4$  at temp.  $700^\circ$   $\longrightarrow$  Lag time was 11 sec
- (b) With 6.5 % of  $\text{CH}_4$  at temp  $1175^\circ\text{C}$   $\longrightarrow$  Lag time was only 0.01 sec

The ignition lag is explained as due to the reaction of Methane with oxygen only often it has absorbed a definite quantity of heat about 2201 K. cal. mol.

#### IV. *Causes of Fire Damp Explosions*

- (a) Foolishness of Miners
- (b) Use of damaged safety lamp and their improper handling.
- (c) Blasting
- (d) Mine fires
- (e) Friction
- (f) Electric Sparks.
- (g) Other special causes.

##### *(a) Foolishness of Miners:*

Smoking, Making fire, opening of flame. safety lamp results in ignition of firedamp.

##### *(b) Use of Damaged F.S.L's and their Improper handling:*

A safety lamp is safe only when its various parts are clean, in good condition, all parts are properly assembled and is properly handled.

##### *(c) Blasting:*

Blasting in coal and road head rippings represented a dangerous source of ignition of fire damp in the part. But in the recent days safer explosions and improved shot-firing techniques are implemented with that the rate of explosion are decreased.

##### *(d) Mine Fires:*

Mine fires may easily bring out about ignition of flammable fire damp mixtures in contact with them.

##### *(e) Friction:*

Friction heating or sparks can ignite flammable firedamp air mixtures. It is broadly divided into 3 types.

- i. Friction between Metal and Metal.
- ii. Friction between Metal and Rock.
- iii. Friction between Rock and Rock

##### *i) Friction between Metal and metal:*

This is due to the metals which oxidize readily. As per experience made at Germany and U.K. the ignition of flammable Methane air mixtures are formed only from aluminum and its alloys but less possibility with iron particles.

##### *ii) Friction between Metal and Rock:*

Siliceous band or inclusions of iron-pyrite modules. Experiments showed that the mixture of the This is due to cutting and drilling operations in seam containing hard rock is for more important than the type of picks or bits used.

*iii) Friction Rock and Rock:*

This is due to friction between rocks caused by fall or caving of sandstone roof rock. The rocks containing hard surfaces such as siliceous or quartz, bearing sand stones can produce ignition.

Mainly Frictional ignition hazard depends on the mixture of the contacting materials. The composition of the flammable gas mixtures. The rate of energy release and the type of frictional contact of the materials.

*(f) Electric Sparks:*

The electrification of coal mines is the ever present source of ignition by electric sparks of not only combustible material but also flammable fire damp air mixtures

Generally electric sparks have much higher temperature than ordinary flames. It may happen that a spark will fail to ignite or flammable gas mixture. This is due to the spark has very short life and in particular time the spark energy may not be suffice to ignite the mixture at that time.

The ignition of fire damp explosions due to electric sparks depends on Methane concentration humidity, O<sub>2</sub> content, temperature, pressure and turbulence.

*(a) The following points are to be observed carefully*

- 1) The mine should be Mechanical ventilated, a reserve or stand by fan (main fan) having independent drive and power circuit should be provided where the gas emission has greater than 5m<sup>3</sup>/Te of daily output.
- 2) The mine equivalent orifice should be as large as possible i.e., >2m<sup>2</sup>.
- 3) Higher ventilation pressure expending 200mm of w.g. should be avoided as far as practicable.
- 4) The entire Mine should be ventilated b exhaust ventilation method.
- 5) The ventilation of mine workings should not be done by diffusion alone.
- 6) Ventilation doors should be correctly isolated and kept closed always.
- 7) Ventilation pressures developed in the development headings should be maintained well, By installing more fans insured of a single an of high pressure the re circulation of air also should be eliminated.
- 8) The Mine ventilation system should be planned so that simple, effective, and reliable ventilation of all workings is assured.
- 9) Adequate are velocities should be maintained while extraction of coal from the working places (1-2m/s) (L 3 M/s).
- 10) Air-leakage should be minimum.

- 11) High standard of ventilation is maintained in the districts liable to out blasts.
- 12) Air-currents and methane emission should be controlled by adopting systematic ventilation survey.

*b. i) Measures Against Ignition of Fire Damp Mixtures*

- 1) All persons should be prohibited from carrying smoke articles, matches, or other spark of flame making devices.
- 2) Naked flame safety lamps are avoided and special attention should be paid conducting gas testing.
- 3) Only approved type of flame of electric safety lamps are used, they should follow these points.
  - i. The lamp should be carried in vertical position.
  - ii. The glass should be protected for splashes of waters.
  - iii. The lamp should not be set down on the floor but should be hand from a substantial support.
  - iv. The lamp should not be allowed to soot or smoke.
  - v. The lamp should but be left un attended in the mine.

Soot→Black powderly substance in smoke.
  - vi. The lamp should not be exposed to string air-currents to prevent the flame from going out”.
  - vii. No combustible material should be ignited by the lamp.
  - viii. When f.s.l. indicates a dangerous percentage of gas during tests, the lamp should be with drawn slowly carefully and promptly to prevent flame from going out and the flame is extinguished suddenly and the lamp should be taken to fresh air and allow to cool before relighting it.
- 4) Only certified flame proof and intrinsically safe apparatus should be used. The apparatus should be properly installed, protected, operated and maintained.

To prevent ignition for electrostatic charges all ventilation ducting should be eartherd and belts are used.

Automatically cut off electrical power supply when Methane concentration, the prescribed maximum value, must be installed in mines.

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

The production of frictional sparks especially caused by metal to rock contact as with cutting, power loading and drilling machines should be avoided.

Precautions should be taken such as appropriate cutting horizon, wet cutting, water spraying and cure of whale jibs.

Adequate ventilation of the cut causing a water spray device or vapoured air provides the most effective method of preventing frictional ignitions with power loading on long wall faces the frictional ignition hazard when SERD, DERD are in operation. Then the standard of ventilation is maintained and water is sprayed and cutting is done simultaneously.

- 6) Spontaneous heating of coal is controlled by good ventilation system.
- 7) Blasting with explosions should be restricted to a minimum. Blasting devices such as Hydro candox, and Air-breaker shells are used for breaking coal.

Pulsed-infusion shot firing the combination with deep hole water infusion is implemented without machine cutting.

**b (ii) When blasting with Explosives following points are observed:**

- a. Only permitted explosives are used.
- b. The length of stemming should be at least  $\frac{2}{3}$ <sup>rd</sup> the length of the hole and be not less than 60cms water stemming has almost replaced clay and sand slowing in western countries.
- c. Shots should be fired where CH<sub>4</sub> percentage is less than minimum ( L 1.25%) as per regulations.
- d. Maximum charge in a hole should not exceed the official or prescribed charge limit.
- e. Blasting should be done by trained and experienced the.

In the U.S.S.R. experiments has made to prevent ignition of fire damp the development headings by forming a foampeg at the face by a foam generator just before blasting the results so far obtained are very clearaging.

*c) Control of Fire damp Emission:*

In mines where high fire damp emission are expected draining the gas by bore holes is done.

In seams liable to out bursts of fire damp special prevention are observed in workings pre-draining of fire damp and inducer shot firing are the two important measures against gas out bursts. [Methane Drainage]

*Coal-Dust Explosions:*

*Def:* A coal dust of any industrial dust explosion is a sudden combustion process of great intensity characterized by much destructive effect through pressure and heat.

For an ignition sufficient combustible dust and oxygen ration must be prevent and the source of ignition in the form of flame must be prevented.

**1) Flammable or Explosive Limits**

Flammable or Explosiveness of a dust is defined as its ability when in the form of cloud to spread ignition to all points where dust air mixtures are of corresponding concentration are prevent.

Experience has shown that a coal dust explosion often develops in stages. The first stage of ignition is often a “puff” which is a sudden combustion of a part or whole of air borne dust marked by a very high temperature but with out any dynamic.

**Lower Limit:**

The lower limit is not as absolute quantity. It depends upon the particle size, chemical composition of dust, Nature and Intensity of the ignition source, Time of contact with source.

For Bituminous Coal  $\rightarrow \frac{30 \text{ to } 70 \text{ g/Nm}^3 \text{ air}}{\text{voilume}}$

The dust cloud observes a cap lamp at a distance of 3.5 mts

**Upper Limit:**

The Upper Limit of flammability is indefinite because of difficulty in maintaining dust clouds of high concentration.

For Bituminous Coals  $\rightarrow 2000 \text{ gms/Nm}^3$

Most violent explosives  $\rightarrow 400 \text{ to } 500 \text{ g/Nm}^3$  of coal dust concentration.

The min amount of coal dust that can propagate an explosion is very small i.e., about  $40 \text{ g/mm}^3$  which is no mole than the thickness of the layer of the proper over the periphery of a  $2.4\text{m} \times 2.7\text{m}$  road way. It has a min explosive concentration of about  $0.05 \text{ to } 0.07 \text{ kg/m}^3$

For compete combustion  $113/\text{Nm}^3$  of pure carbon would be sufficient.

Where the coal dust initially raised begins to burn, a further blast is created and this may raise more dust ahead of the flame making the process self sustainily.

**6. Causes of Coal dust Explosions in Mines**

- 1) Naked Flames
- 2) Friction
- 3) Electric Sparks
- 4) Fire damp Explosions.

**1) Naked Flames:**

A Naked Flame is the earliest means of ignition a dust cloud as the source of heat is of considerable size and the larger part of the dust cloud can be heated.

**2) Friction:**

Hot surfaces as a result of Mechanical Friction (Rock to Rock, Metal to Rock, Metal to Metal) such as over heated bearings may ignite surrounding explosive dusty atmospheres.

**3) Electric Sparks:**



Electric sparks for shot firing and as at electrical equipment many ignites an explosive dust air mixture, sparks of higher voltage and damperage are usually necessary than in the case of flammable fire damp mixtures.

Static electrical sparks also non ignite the explosive dust air mixtures.

#### 4) *Fire damp explosives:*

A fire damp explosives is the commonest source of initiative of a coal dust explosion.

A fire damp explosion may rise the deposited dust into mine air very quickly before its flame has erased and then propagate as a coal dust explosive. A very small gas explosive may thus bearing about a much bigger coal dust explosive.

This danger is particularly great in long headings than in long coal faces.

### 7. *Prevention and Suppression of coal dust Explosions*

#### 1) *Measures to Prevent/Reduce formation of coal dust in Mines,*

(a) Water infusion at the coal faces→5 to 20 at g (Normal)

Water infusion at the coal faces→80 to 250 at g (high)

The amount of Water required→8 to 101 Ltrs/m<sup>3</sup> of (solid coal)

(b) Wet winning of coal with wet pneumatic picks.

(c) With machine cutting using sharp picks of suitable type, optional cutting and travelling speeds of the machine using gummer we wet cutting.

(d) With power loading using conventional shearer loaders suitable type of pick, drum design proper direction of drum rotation, in two eluring water into the pick clearance lines rushing the cutting edges of picks using external water sprays.

Internal water pressure about 115 kg/cm<sup>2</sup> have been formed to be more effective than external water sprays.

(e) Wetting through coal pile before it is naturally of mechanical loading.

(f) Use such type of conveyors with which the dust production in mining.

(g) Water spillage or degradation of coal during transportation by

☆ Using un damaged dust tight cars

☆ Avoid over loading

☆ Water spraying the full and empty tubs during transport.

☆ Maintain the haulage track in good condition suitable capacity of conveyor, bunker etc. should be used for avoiding spillage.

(h) Restricting velocities of air currents to less than 3m/sec

(i) Prevent dust accumulation in mine carrying by.

- (j) Dry suction at loading and unloading points .
- 2) Cleaning systematically and regularly the main haulage roads and main return air ways of dust (3 to 4 year) by transportable (mobile) suction apparatus.
- 3) Installing skip hoisting in upcast shaft.
- 4) Location of dry coal preparation plants atleast 80 mts, away from the D.C shaft.
- 5) Select a method of winning with which the dust production is least.

*Measures against ignition of Dust accumulation:*

- a) Measures against ignition of flammable fire damp mixtures.
- b) Neutralisation or consolidation of dust at working coal faces with in radius of 10-20mts before shot firing by means of insect water or stone dust.
- c) Neutralisation of dust in Road ways thrown of water, stone dust -----salts----

*iii) Measures against explosion Propagation:*

1. Generalised wetting of coal dust
2. Generalised stone dusting.
3. Stone dust barriers
4. Explosive stopping
5. Salt Zones
6. Water barriers
7. Triggered barriers

**10.2 .5 Purpose And Location Of Stone Dust Barriers:**

*Purpose:*

Stone dust has the effect of absorbing the heat that would otherwise ignite the coal dust cloud and the stone dust prevents coal dust from reaching the ignition point. Dust prevents coal dust from reaching the ignition point. The most generally accepted index of explosibility of a coal dust at present is the amount of stone dust which must be added to it to make it non-explosive. The index can be expressed in two ways, either directly by the weight of the stone dust added, in kg per kg of dust being tested, or by the percentage of ash content in the mixture after the stone dust has been added, including the natural ash content in the mixture after the stone dust has been added, including the natural ash content of the dust being tested.

*Location of the Stone dust barrier:*

This should be sited nearer to the source of ignition. A barrier should be provided at a distance of not less than 150 m from the nearest working face and at not more than 400 m from the farthest face. The heavy barrier will have to be provided in all entries to the district. The places where barrier are to be sited may be reduced by brick in cement in the entries other than those essentially required for ventilation and haulage. The shelves of the barrier would ordinarily

be included in about one pillar length and as far as possible, the shelves should not be positioned at the junction.

In the long wall workings of barrier of light type should be installed in all long wall gate conveyor roads within the range of 50-120m from the nearest point of the face. A second barrier should be placed further out by 200-350 m from the face.

### 10.2.6 Water Barriers

Since the early 1960s, interest has revived in the use of passive water barriers, also called water-trough barriers as alternative to stone-dust barriers for suppression of coal-dust explosions in mines. Water has the following advantages over stone dust:

- a) Its heat capacity is about five times that of dust
- b) Its efficiency is not affected by underground climatic condition; and
- c) It is available in all mine roadways.

A water barrier consists of a number of water-filled troughs or containers of suitable material supported on horizontal shelves in the vicinity of the mine roof as in the case of a stone-dust barrier. The containers shatter or burst under the action of the pressure wave or shock wave ahead of the propagating flame of an explosion releasing and dispersing water in all directions in the path of the explosion flame. In some countries, the water barriers have become the principal means of protection against coal-dust explosions.

Water barriers offer advantages over stone-dust barriers in cheapness and ease of installation and maintenance. Extensive tests on the performance of water barriers carried out in the Tremonia Experimental Mine, F.R.G., showed that in quenching explosion flames, the water barriers are roughly equivalent to the stone-dust barriers and that 200 litres of water per square metre of roadway cross-section would be necessary which would have the same effect as 400 kg stone dust per square metre on Dortmund Shelves [52]. Besides the magnitude of the dynamic pressure, the shattering of the water troughs is influenced by the trough material used, trough shape, method of installation, and trough lids or covering. Wood and sheet steel are not suitable materials. Troughs made of certain varieties of hard PVC or foamed polystyrol (Styropor) have been found to be most suitable materials as they are easily shattered at low wind pressures giving good water distribution. The troughs must be designed so that they maintain their shape with little sacrifice of their fragility. Troughs with approval certificates should only be used. The method of installation of the troughs in roadway cross-section exercises a great influence on the shattering of the troughs. Troughs placed with their longer axis at right-angles to the roadway axis offer greater frontal area to the dynamic pressure than when they are placed parallel to the roadway axis.

Contrary to expectations, troughs supported in the roadway cross-section with their edges resting on transverse supporting frame have been found to shatter more easily than troughs supported on transverse bars. This is because the former are subjected to full dynamic pressure and cannot be displaced as happens with the latter. Also, the use of loose lids to prevent evaporation of water does not affect in any way the distribution of water in the direction of roof as the lid lifts itself off the trough.

Water barriers are at present widely used in the West German Coal Mines. Their design and installation are laid down in the regulations. Depending on the method of support, two

types of water barriers have been approved for use in mine roadways less than 4 m in height or less than the maximum width at the site of installation-Type 1 and Type 2. In Type 1 barriers, the troughs are supported with their total upper lip surface resting on transverse supporting frames while in Type 2 barriers, the troughs are placed over transverse bars. Figure 2.45 illustrates the prescribed method of installation of water troughs carried by a shelf in roadway cross-section as well as the two types of approved trough construction.

The following rules govern the erection of water barriers in German mines:

- a) The water barriers must contain at all times a total quantity of at least 200 litres of water per square metre roadway cross-section or at least 5 litres per m<sup>3</sup> roadway volume and must be at least 20 m long.
- b) The distance between two shelves must be at least 1.2 m.
- c) The space between lips of adjacent troughs carried by a shelf must not be greater than 1.20 m and the total space between troughs in a row of troughs must not exceed 1.50 m. A row of troughs is identified as a number of troughs supported across the roadway from side to side.
- d) The distance between the outer troughs of a row and roadway side or rib must not exceed 1 m. Where this distance exceeds 1m, an additional trough containing at least 30 litres of water must be installed at the rib.
- e) The troughs must cover, at the site of installation, at least 50 percent maximum roadway width for roadway cross-sections exceeding 14 m<sup>2</sup>.

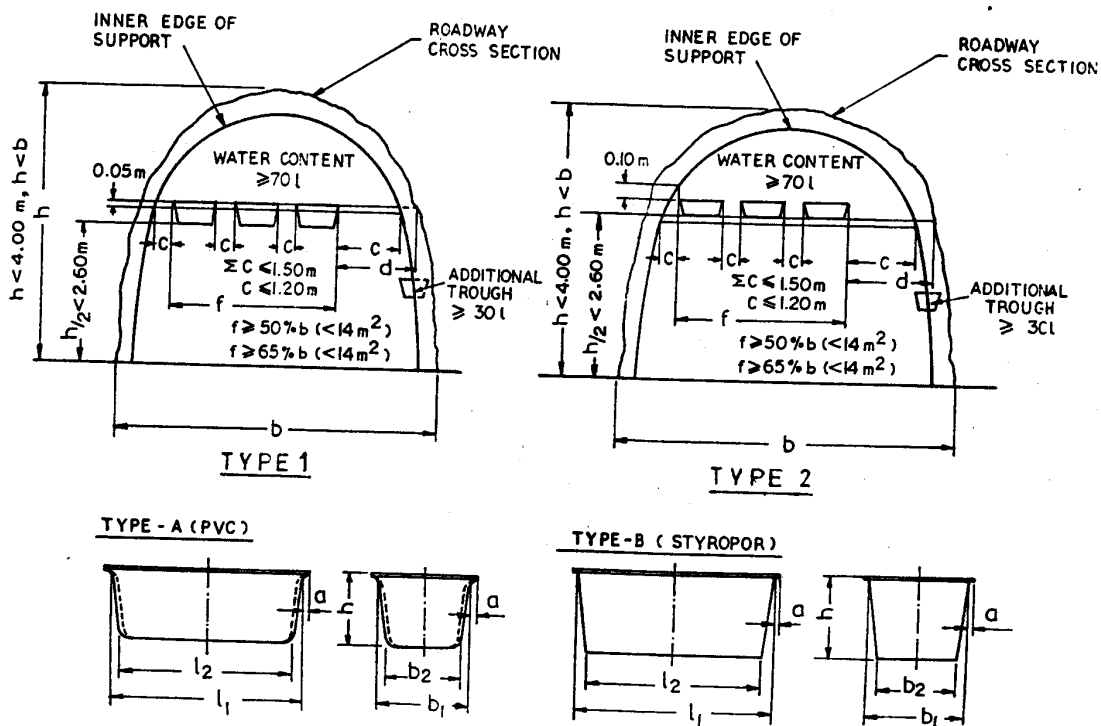
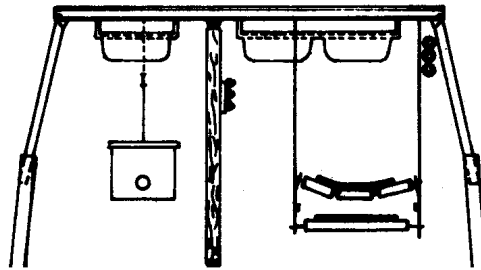


Fig. 2.45: German Water (trough) Barrier (schematic)  
 $l_1 = 760$   $l_2 = 720$   $a = 25$   $b_1 = 500$   $b_2 = 450$   $h = 270$   $\text{Vol} \approx 83\text{ l}$

- f) The bottom of the troughs must be at a height of at least half the height of the roadway but not exceed 2.60 m.
- g) When the top lip or edge of the troughs is higher of at least half the height of the roadway but not exceed 2.60 m.
- h) When the top lip or edge of the troughs is higher than 1.70 m above the roadway floor, the trough walls must be designed so that the water level can be recognized against marked graduations or a float provided in each trough.
  - i) With Type 2 barriers, the vertical space between the top edge of the trough and the inner edge of the roof support must be at least 10 cm.
  - j) The troughs must carry at least 70 litres of water.
  - k) At all places where barriers are installed, water from a water pipe must be available. Water hoses must be provided.
  - l) Water barrier must be located at least 100 m away from stone-dust barriers.
  - m) The distance between barriers must not be greater than 200 m in gate roadways and 400 m in main roadways.

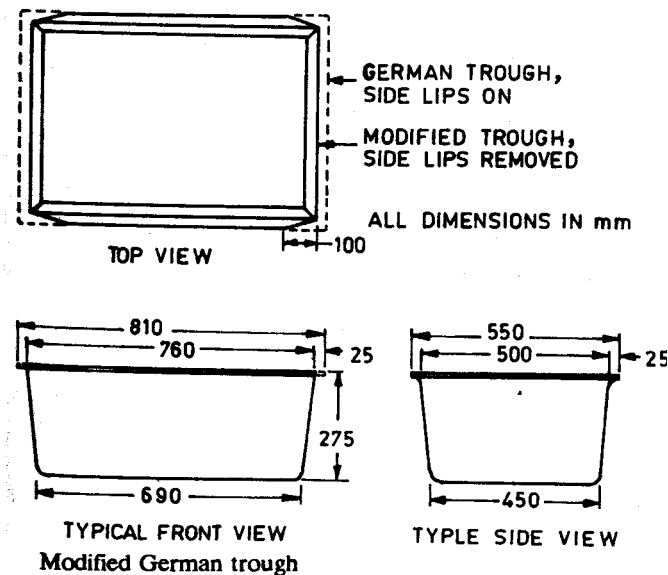


**Water troughs in the cross-section of the gate road of an advancing  
Long wall**

Fig.

Figure --- shows the modified German trough recommended by the U.S. Bureau of Mines for use in water barrier installations on belt conveyor roads [53]. In this design, the side lip supports are removed and the front and rear lips of the modified trough rest on the frame work so that, in the event of an explosion, the trough falls pivoting about its rear lip. Such a design is expected to be effective in suppressing weak coal-dust explosions.

### 10.3 SUMMARY



#### *Types of explosions*

##### 1. Fire Damp Explosion

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

Lower flammable limit of explosion is 5% of  $\text{CH}_4$ , 12% of  $\text{O}_2$  causes for fire damp explosions are use of damaged flame safety lamp foolishness of workers, blasting, Mine fires, friction electric sparks, this can be prevented, dissolving the accumulation of  $\text{CH}_4$ , taking measures against ignition, control of fire damp explosion.

##### 2. Coal Dust Explosion

Flammable or explosiveness of a dust is defined as its ability when in the form of cloud to spread ignition to all points.

Naked flames, friction, Electric sparks, Fire damp explosion are causes for Coal Dust Explosion.

Measures are taken to prevent the coal dust explosion. Those are water infusion, wet drilling, wetting of the coal face, less dust producing conveyors, restricting the velocities of air, dry section, cleaning etc.,

## 10.4 ASSESMENT

### 10.4.1 Short Answer Type Question

- 1) List different types of Explosion.
- 2) Explain Purpose of Stone dust Barrier.
- 3) States the application of water Barrier.

### 10.4.2 Essay Type Question:

- 1) List the causes of Fire Damp Explosion.
- 2) List the preventive measures against Fire Damp Explosion.
- 3) List the causes of Coal Dust Explosion.
- 4) List the preventive measures against Coal Dust Explosion.

### 10.4.3 Objective Question

1. The Lower Limit of Flammability of CH<sub>4</sub> is \_\_\_\_\_%.  
 a) 7                      b) 5                      c) 2                      d) 10                      [b]
2. The Upper Limit of Flammability of CH<sub>4</sub> is \_\_\_\_\_%.  
 a) 10%                      b) 12%                      c) 8%                      d) 15%                      [d]
3. The required % of Oxygen for fire Damp Explosion are \_\_\_\_\_.  
 a) 12,20                      b) 8,15                      c) 12,25                      d) 2,10                      [a]
4. \_\_\_\_\_% of N<sub>2</sub> gas required to inert CH<sub>4</sub> gas.  
 a) 20                      b) 30                      c) 81                      d) 70                      [c]
5. \_\_\_\_\_% of Rock Dust (CaCO<sub>3</sub>) required to inert CH<sub>4</sub> gas.  
 a) 60                      b) 70                      c) 80                      d) 95                      [d]
6. Lower Limit of Coal Dust Explosion of Coal Dust \_\_\_\_\_.  
 a) 30-300 g N/m<sup>3</sup>                      b) 0-100 gN/m<sup>3</sup>  
 c) 0-50 gN/m<sup>3</sup>                      d) None                      [a]
7. Upper Limit of Coal Dust Explosion of Coal Dust \_\_\_\_\_.  
 a) 100-200 gN/m<sup>3</sup>                      b) 200-300 gN/m<sup>3</sup>  
 c) 400-500 gN/m<sup>3</sup>                      d) 500-600 gN/m<sup>3</sup>                      [c]
8. Water infusion required to diffuse Coal Dust is \_\_\_\_\_.  
 a) 0-50 litres/m<sup>3</sup>                      b) 8-100 litres/m<sup>3</sup>  
 c) 100-200 litres/m<sup>3</sup>                      d) 200-300 litres/m<sup>3</sup>                      [b]

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