

# **LECTURE – 4**

**THE CONTENTS OF THIS LECTURE ARE AS FOLLOWS:**

## **1.0 METHANE**

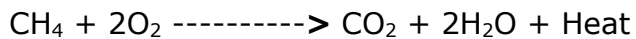
- 1.1 Physical Properties
- 1.2 Explosibility Curve of Methane
- 1.3 Lag on Ignition
- 1.4 Classification of Coal Mines based on Methane Emission
- 1.5 Occurrence of Methane
- 1.6 Desorption of Methane and its Emission to Underground Openings

## **REFERENCES**

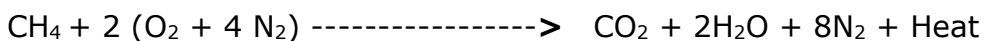
## 1.0 METHANE

### 1.1 Physical Properties

Methane is a colorless, odorless and tasteless gas. 1 Kg of methane at NTP (273.15K and 101.33KPa) has a mass of 0.7168 kg. This gas is lighter than air as its specific gravity is equal to 0.559. That is the reason why it tends to rise to the roof of a mine working. Methane becomes liquid below 112 K and solidifies below 90.5 K. Methane gas is poorly soluble in water, but is soluble in organic solvents like alcohol and ethers. This property of methane is utilized during drainage of coal bed methane. It burns with a blue flame and produces carbon dioxide and water as products.



This exothermic reaction is a chain reaction and under suitable conditions gets self accelerated and leads to an explosion. The combustion of methane in air can be represented as follow:



The ignition temperature of methane is roughly 650°C. This means that only very hot spark or flame will be able to ignite methane. When methane, even though dilute, is brought in contact with a flame, it burns. It is important to note that, when the concentration of methane is low, the methane molecules are far apart from each other. Therefore burning of one molecule of methane does not create sufficiently high temperature so as to ignite the molecule adjacent to it. With increase in the concentration of methane, each molecule of methane is able to ignite the molecule adjacent to it which spreads the flame rapidly throughout the mixture. In such condition an explosion takes place and such a mixture of methane and air is called an inflammable mixture. If the mixture contains too much methane, the oxygen percentage in the mixture is reduced which causes reduction in the rate of combustion

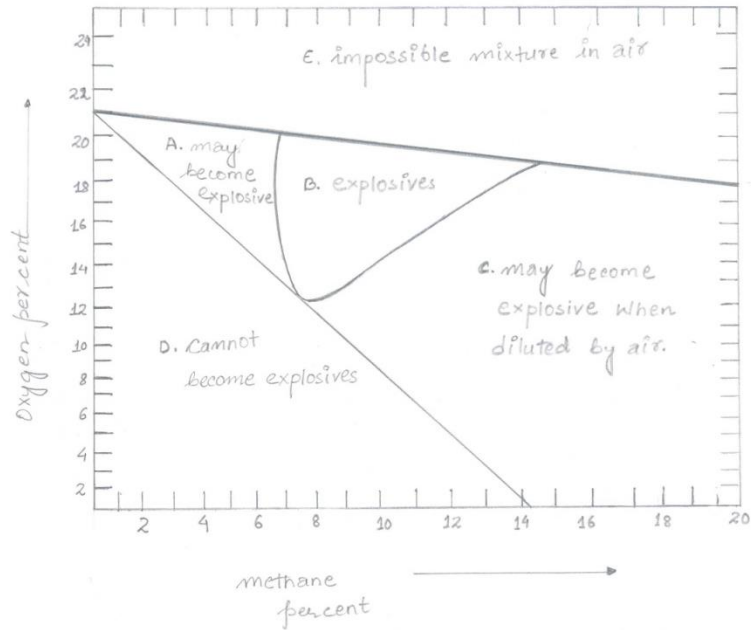
which in turn causes insufficient development of heat to propagate a flame and therefore explosion does not take place.

When wire gauze is held horizontally in a jet of methane, it will be possible to lit the gas above the wire gauze and it will not burn below the gauze or vice-versa. This is because, the wire gauze carries away the heat from the flame so rapidly that the temperature on its other surface is reduced to below 650°C. Due to this, the methane on that side does not ignite.

## **1.2 Explosibility Curve of Methane**

If you want to find out the flammability of methane-air mixtures, explosibility curve of methane is extremely useful. There is proper oxygen balance with methane content of 9.8 % by volume in the air. Because of this reason, at this concentration of methane i.e., 9.8 %, the mixture is most explosive. Another important point which you should remember is that, the explosions caused due to methane gas are not as violent as those of commercial explosives. This is because of the density difference. The density of methane-air mixtures is around 1.15 kg/m<sup>3</sup> whereas the density of gun powder is 1000 kg/m<sup>3</sup> and for nitroglycerine it is 1600 kg/m<sup>3</sup>. The explosible range for methane in air is 5 % to 15 % by volume. As told earlier, most explosive mixture of methane gas occurs at 9.8 %. The lower flammable limit of methane gas is almost constant whereas the upper limit reduces with decrease in the oxygen percentage in the air.

Fig. 1 illustrates a diagram which was initially developed by scientist H. F. Coward in 1928. This diagram helps us to find the flammability of methane-air mixtures as the composition changes. It is also popularly known as Cowards Diagram.



**Fig. 1 Explosibility curve of methane (Source: McPherson, 1993)**

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

- In region A, the mixture is not flammable. However, it may become flammable if further methane is added to it. This is possible, when that particular portion of the mine is sealed off.
- In region B, the mixture is explosive with a minimum nose value at 12.2 % oxygen (The nose limit represents the most dangerous mixture as this mixture requires the largest amount of excess nitrogen to render it non-flammable. The ratio of the percentage of excess nitrogen to the percentage of a combustible gas at the nose limit is called 'Inert Factor').
- Region C and D illustrate mixtures that may exist in sealed areas at all.
- A mixture in region C will become explosive if the mixture is diluted by incoming air.
- In region D, the mixture can't become explosive.

### 1.3 Lag on Ignition

Lag on ignition is an important characteristic of methane gas. Methane gas starts burning only after absorbing 92.53 KJ/mol heat. Thus 'lag on ignition' is defined as the time interval between the exposure of "CH<sub>4</sub> – Air" to an igniting source to the appearance of flame. This lag on ignition is dependent on the temperature of the igniting source. As for instance, at 650 °C, the delay is around 10 seconds, at 1000 °C, it is 1 second and 1200 °C it is 1/15<sup>th</sup> of a second. This property of methane gas is utilized in designing of permitted explosives which are prescribed for use in underground coal mines. These permitted explosives produce a flame of a very short duration. In this time period/duration, methane doesn't get enough heat required for its ignition. Thus the permitted explosives can be used safely in underground coal mines. One important point to be remembered is that the presence of hydrogen or other gases reduces the lag.

### 1.4 Classification of Coal Mines Based on Methane Emission

In India, coal mines are classified into three categories based on methane emission. The details of this classification is given in Table 1.

**Table 1 Classification of coal mines**

Degree of gassiness	Percentage of inflammable gas in general body of air	Rate of emission of gas in m <sup>3</sup> /ton of coal raised
I	< 0.1 and	<1
II	> 0.1 and/or	1-10
III	--	>10

As can be seen from Table 1, for underground coal mines to come under Degree – I gassy mine category, both the "percentage of inflammable gas in general body of air" as well as "rate of emission of methane gas in m<sup>3</sup>/ton of coal raised" must be satisfied. For underground coal mines to come under

Degree – II gassy mine category, any one of the conditions i.e., “percentage of inflammable gas in general body of air” or “rate of emission of methane gas in m<sup>3</sup>/ton of coal raised” is sufficient.

### **1.5 Occurrence of Methane**

Methane is usually found in coal mines and sometimes in the tunnels passing through carbonaceous shale. Methane is the major constituent of firedamp [a mixture of air which mainly consists of methane (80-96%) with other minor gases such as nitrogen, ethane, carbon dioxide etc], which is a common gas mixture in mines.

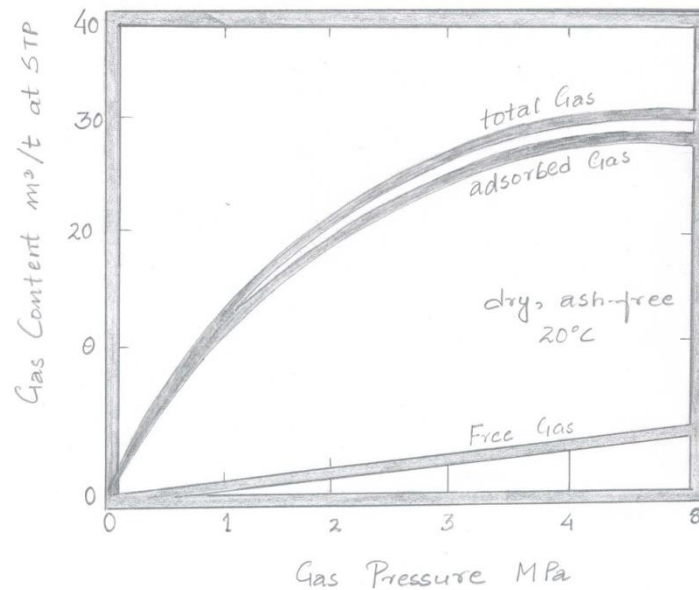
The vegetable matter composed mainly of cellulose and lignin is decomposed by bacterial action which produces methane and carbon dioxide. That is why methane is sometimes called as marsh gas. The process continues and in the early stage of coalification, much of methane escapes because of poor confinement but largely retained in higher rank coal. Coal has large number of small pores and correspondingly high internal surface area. Porosities of coal may vary from 1 % to more than 20 %.

Methane exists in coal in two different forms which are referred as free gas and adsorbed gas. In free gas, the methane molecules are free to move within the pores. In adsorbed state, the methane molecules are adsorbed on to the coal surface. Around 95 % of the total methane content in coal is in adsorbed state which is due to very high gas pressure. Fig. 2 depicts a typical graph showing adsorbed, free and total gas isotherms for methane in coal. Fig. 3 and Fig. 4 indicates that, the rate of desorption with respect to gas pressure increases as the gas pressure falls.

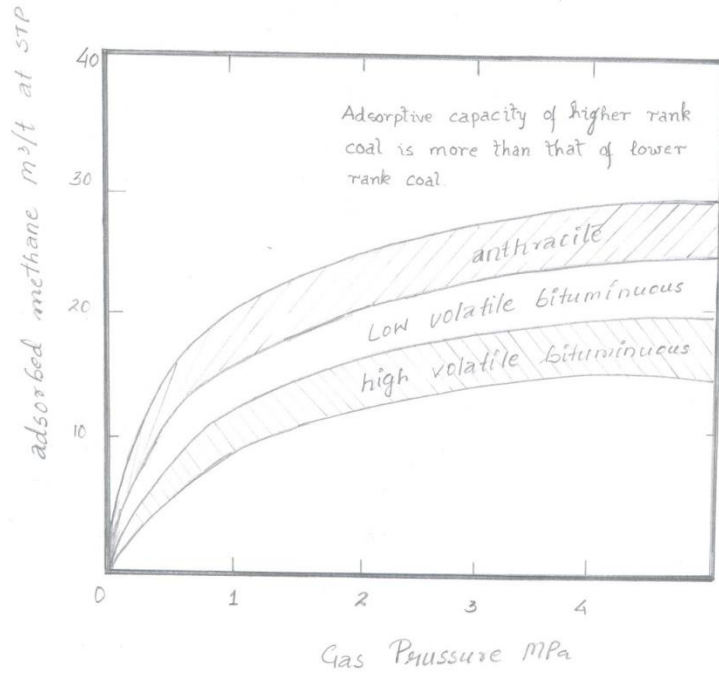
We have already discussed that methane is not the only gas that is trapped in the coal seam or strata. The other gases which are also found in coal seams are carbon dioxide, carbon monoxide, nitrogen, etc. Of these, carbon dioxide is the most important one. It is the carbon dioxide which is a major

constituent in coals of lower grade, while methane is the major constituents in the higher rank coal. For example, in lignite, bituminous and sub-bituminous coal, carbon dioxide is the most significant one. However, in anthracite (which is the highest rank coal) methane has major part compared to carbon dioxide. One tone of anthracite is known to have approximately 765 m<sup>3</sup> of methane and 565 m<sup>3</sup> of carbon dioxide (Hartman, 1982).

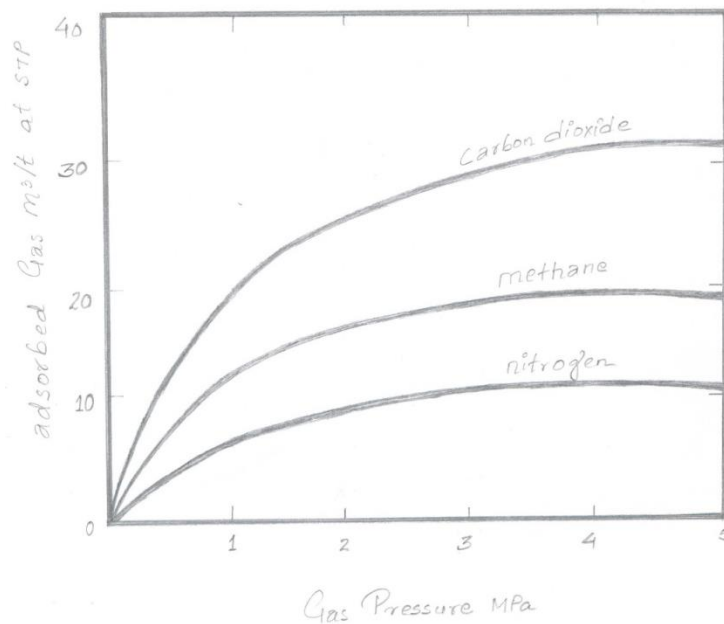
We already know that during coalification, a fraction of these gases escape out. The amount of gas retained per ton of coal is called seam gas content (includes all gases). It is generally expressed in m<sup>3</sup>/ton. Another important term to know is, the specific methane emission, defined as the volume of methane emitted per ton of coal. It is used as an index for/of seam gas content.



**Fig. 2 Typical graph showing adsorbed, free and total gas isotherms for methane in coal (after McPherson, 1993)**



**Fig. 3 variation of adsorbed methane with gas pressure (after McPherson, 1993)**



**Fig. 4 Variation of adsorbed gases with gas pressure (after McPherson, 1993)**



## **1.6 Desorption of Methane and its Emission to Underground Openings**

Methane is emitted mainly from coal seams and associated strata in an underground mine. Methane in the coal seam has considerable pressure. But the mine workings have pressure equal to that of atmospheric pressure. Hence the adsorbed gas in the coal gets desorbed because of the lowering of pressure when the rock containing the gas is drilled /cut. Methane tends to migrate to low pressure zones. Speedy migration of methane takes place through macro cracks and fissures and slow migration takes place by permeation through micropores and micro cleavages. Major channels for gas migration are faults and joints. Dykes and sills also provide a path for methane migration.

When coal is cut, transported etc, desorption of methane occurs. The size of coal produced has a great influence on the amount of gas emitted at the face. Large lumps of coal release only 2 % of their total gas content in the first 10 minutes whereas coals of 0.25 – 1.0 mm size release 40 % and coal of size less than 0.25 mm release 66 % of their total gas content.

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