LECTURE – 1

THE CONTENTS OF THIS LECTURE ARE AS FOLLOWS:

1.0 GENERAL COMPOSITION

Let me tell you that air is a non-homogeneous mixture of different gases. There are two ways by which we can represent the composition of air:

i) Percentage of gas by volume

ii) Percentage of the gas by mass

1.1 Composition of Dry Air

The composition of dry air at sea level is given in Table 1.

Table 1 General composition of air (Bolz & Tuve, 1973)

S.No.	Gas	Volume (%)	Mass (%)	Molecular weight(kg/kmol)	Molecular weight in air
1.	Nitrogen	78.03	75.46	28.015	21.88
2.	Oxygen	20.99	23.19	32.00	6.704
3.	Carbon dioxide	0.03	0.05	44.003	0.013
4.	Hydrogen	0.01	0.0007	2.016	0
5.	Monatomic gases(Ar, Rn, He,Kr, Ne)	0.94	1.30	39.943	0.373
	TOTAL	100.00	100.00		28.97

It is important to note that, the composition of different gases (in dry air) by mass is a fixed one whereas the percentage composition of the gases by volume or mass in wet air i.e., air containing moisture is dependent on humidity or the moisture in the air. This is because of the fact that with change in the humidity, the volume and the density of air changes, which results in the change in volume percentage.

Another important point about gases is that, if two gases of different densities are mixed, they will stay mixed forever. Further, if two gases are brought into contact with each other, they will mix by their own. This also happens (i.e. mixing of gases) when the two gases are separated by a thin porous membrane. This phenomenon of gases is called diffusion.

The following Table 2 gives the general air constants which is useful in ventilation and air conditioning work (Bolz and Tuve 1973):

Table 2 General air constants

Properties	**Constants**
Molecular mass	28.97
Specific gravity (s)	1
Gas constant (R)	287.045 J/kg.K
Specific weight at standard condition (at sea level, 760 mm Hg and 70$^\circ F$)	1.2014 kgf/m^3
Standard barometric pressure (at sea level)	760 mm Hg or 101.33 kPa
Specific heat at constant pressure, c_p	1.006 kJ/kg $^\circ C$
Specific heat at constant volume, c_v	0.717 kJ/kg $^\circ C$
Ratio of specific heats at constant pressure and constant volume ,γ	1.402

1.2 Requirement of Sufficient Quantity of Air in Mines

Air is required in mines for four important reasons namely
- to supply oxygen for breathing
- to remove heat from underground environment
- to dilute the presence of dust and various unwanted gases
- to remove dust and unwanted gases

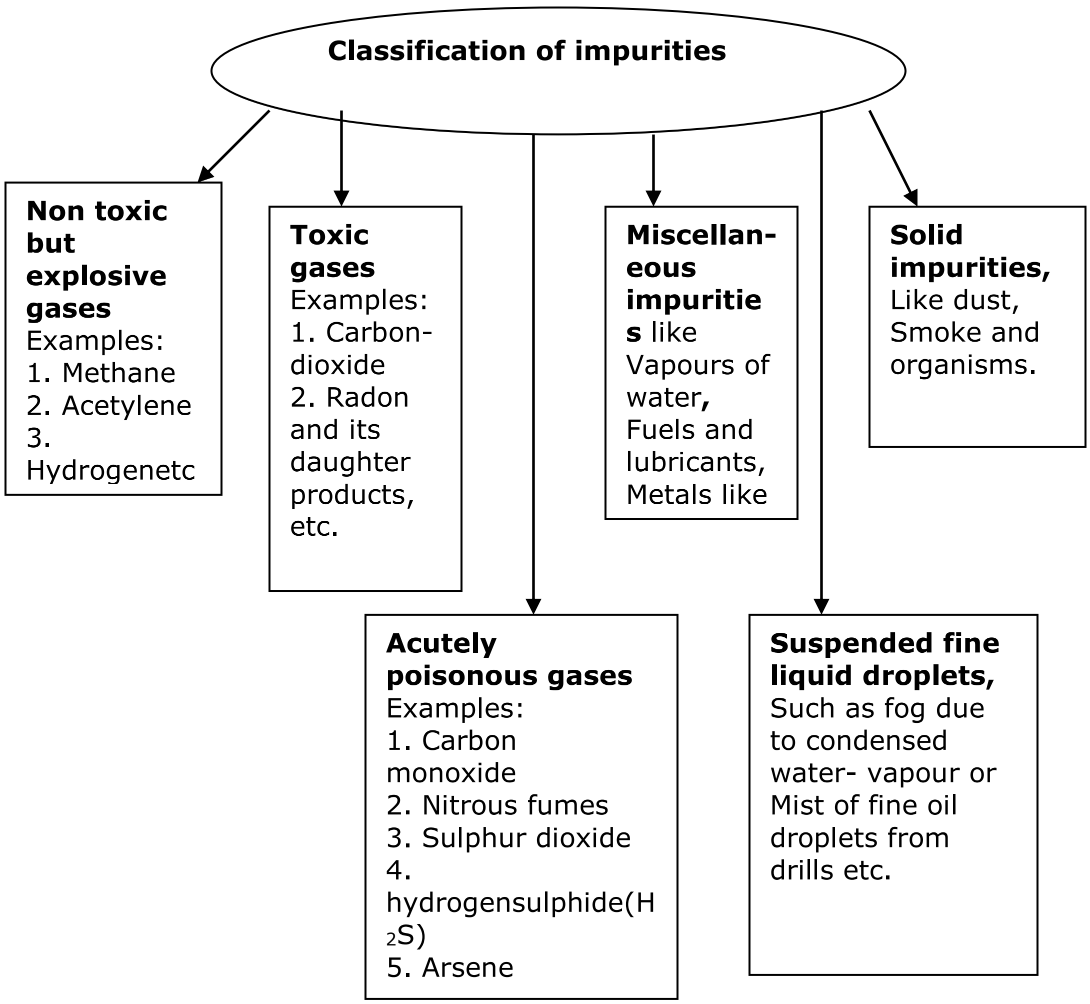

Fig. 1 Classification of mine impurities

2.0 IMPURITIES IN MINE AIR

When air flows through the mine environment, its composition changes due to addition of different kinds of impurities along its path. These impurities are carbon dioxide, carbon monoxide, oxides of nitrogen, sulphur dioxide, methane etc. In mines where cooling plants are used, the mine air also picks up Freon 11 and Freon 12. Some amount of water vapour is also present in the form of moisture in mine air. The classification of impurities present in mine air is explained with a flow chart in Fig. 1

All the above mentioned gases become harmful to humans if their concentrations exceed a certain ceiling (upper) limit. These concentrations are represented in various ways and are collectively termed as Threshold limit values (TLV).These values help in identifying the exposure levels for the mine gases below which there is no significant effect on the health of workers.

3.0 THRESHOLD LIMIT VALUES (TLV):

The threshold limit values (TLVs), as recommended by American Conference of Governmental Industrial Hygienists (ACGIH), are defined as the concentration of different gases (impurities included) and conditions to which it is believed that nearly all workers may be repeatedly exposed day after day without adverse health effects. The determination of TLVs of different gases is based on the information available from industrial experience, experimental studies on human beings and animal studies, etc. It is quite possible that the values recommended by ACGIH may not be suitable to every worker or every age group. These are the average estimates and may change with the change of place, climate etc.

When we utilize TLVs, three values are dealt with for every gas (or substance). They are discussed with the help of a flow chart in Fig. 2.

THRESHOLD LIMIT VALUES (TLVs)

It is the maximum/minimum concentration of constituents of air to which a person can be exposed, such that there is no adverse effect on the person's health/safety.

Time weighted average (TWA)

It is the average concentration to which nearly all workers may be exposed over an 8 hour shift and 40 hour work week without known adverse effect. In industries, it is the TLV-TWA which is generally considered as TLV.

Short-term exposure limit (STEL)

It is a time weighted average concentration occurring over a period of not more than 15 minute, i.e. concentration above TWA and up to the STEL should not last for longer than 15 minute. It is also recommended that such condition should not occur more than four times per day nor at intervening intervals of less than one hour. Further, the daily TLV-TWA is not exceeded.

Ceiling limit

It is the concentration that should not be exceeded at any point of time. This is usually used for the most toxic gases/ substances.

Fig. 2 Threshold limit values

3.1 Threshold Limit Values for Gas Mixtures

In an atmosphere, if there are two or more airborne pollutants (gaseous or particulate) that have adverse effects on the same part of the body, then the threshold limit value should be calculated based on their combined effect. This is calculated as a dimensionless sum as shown below.

$(C_1/T_1) + (C_2/T_2)$ +------+ (C_n/T_n) for 'n' number of pollutants

Where C= measured concentration
T = corresponding threshold limit value

If the above sum exceeds unity, then the threshold limit value of the mixture is said to be exceeded.

4.0 RELATIVE DENSITY AND SPECIFIC GRAVITY OF GASES

Before going for discussion on different gases, it is important to know about the relative densities of different gases which are very often called as density of a gas. To calculate the density of a gas or more precisely the relative density, it is important to know the atomic masses given below:

Hydrogen = 1; Carbon = 12; Nitrogen = 14; Oxygen = 16; Fluorine = 19; Sulphur = 32; Chlorine = 35.5

With the help of atomic masses, the relative density of a gas can be calculated. For instance,
The mass of a molecule of oxygen (O_2) = 2 x 16 = 32
The mass of a molecule of hydrogen (H_2) = 2 x 1 = 2

Therefore, oxygen gas is (32/2 = 16) sixteen times heavier than hydrogen gas.

Thus from the above we see that in case of relative density, the density of a gas is compared to that of hydrogen gas**.** In general, when the density of a gas is spoken of, it is understood to be compared with hydrogen gas as a standard taken as 1. The density of air is 14.4 and that of oxygen is 16.0. This means, air and oxygen are respectively 14.4 and 16 times as heavy as hydrogen.

In ventilation, we are more interested in knowing whether gases are heavier or lighter than air.

As we all know that air consists of roughly 80 % nitrogen with a molecular mass of 28 and 20 % oxygen with a molecular mass of 32.
Therefore, air has the same density as a gas with a molecular mass of (0.8 x 28 + 0.2 x 32) = 28.8 ≈ 29

Now, hydrogen has (2/29 = 0.07) 0.07 of the mass of an equal volume of air. In other words, the specific gravity of hydrogen relative to air is 0.07.
The molecular mass of carbon dioxide (CO_2) = 12 + 16 + 16 = 44. Therefore its specific gravity = 44/29 = 1.5.

When the specific gravity of a gas is mentioned, it should be understood that the comparison is made with air as the standard. As for instance, the specific gravity of carbon dioxide is 1.5 and that of methane is 0.5. This means that carbon dioxide is 1 ½ times heavy and methane is half as heavy as air, the specific gravity of air being one. On the other hand, density is compactness of mass and has reference to the amount of matter contained in it for a given volume. The density of a gas is compared with that of hydrogen gas which is taken as standard i.e. 1. For instance, oxygen gas has a density of 16. This means that oxygen gas is 16 times heavier as that of hydrogen gas. Both the density and specific gravity of a gas are affected by temperature and pressure. With increase in temperature, the density of a gas reduces. The pressure affects the volume and therefore the specific weight* of a gas. Therefore, the comparison of all densities and specific gravities is made at the same standard temperature and pressure.

It should be specific weight and not simply weight. Temperature and pressure do not play any role in varying mass of air. Also 'g' is constant. Therefore, changing density changes specific weight and not weight.

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