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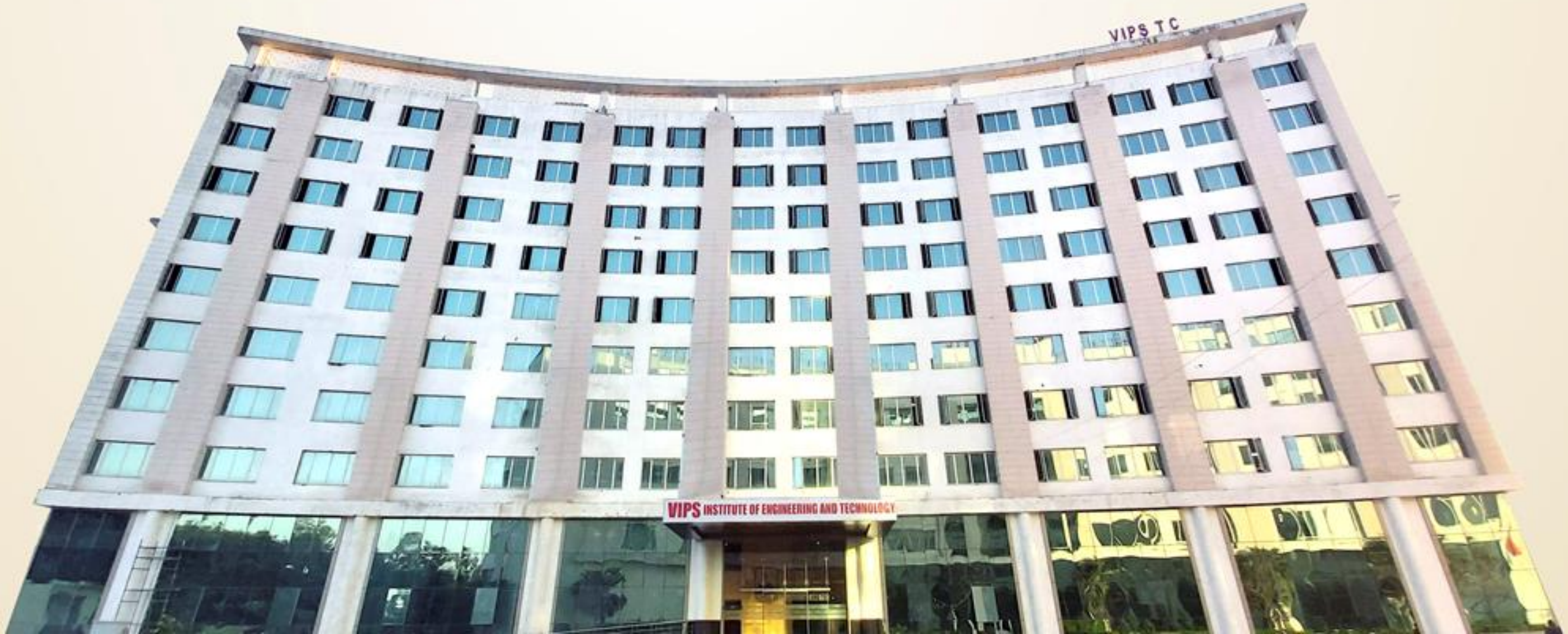
IN PURSUIT OF PERFECTION

COLLEGE OF ENGINEERING



Combustion

- Combustion is an exothermic chemical reaction, which is accompanied by development of heat and light.
- For proper combustion, substance must be brought to its **ignition temperature.**
- Complete combustion : total oxidation of fuel (adequate supply of oxygen needed)
- Oxygen is the key to combustion

Air for Combustion

- Air : 20.9% oxygen, 79% nitrogen and other
- Nitrogen:

  (a) reduces the combustion efficiency

  (b) forms NOx at high temperatures
- Carbon forms-

  (a) CO2

  (b) CO resulting in less heat production

Calculation of Air Required

Following elementary principles are applied, to find the amount of oxygen or air required for combustion of a unit quantity of a fuel.

1. Substances always combine in definite proportions and these proportions are determined by the molecular masses of the substances involved and the products formed.

Eg., $C\ (s) + O_2\ (g) \rightarrow CO_2\ (g)$

Mass proportions 12 32 44

Similarly, $2H_2\ (g) + O_2\ (g) \rightarrow 2\ H_2O\ (g)$

$2 \times 2 = 4$ 32 $2 \times 18 = 36$

2. 22.4 L of any gas at STP (0^oC and 760 mm pressure) has a mass equal to its 1 mole. Thus, 22.4 L of CO_2 at STP has a mass of 44 g (molar mass of CO_2).

3. Air contains 21% of oxygen by volume and 23% by mass.

i.e., 1 kg of oxygen is supplied by:

= (1x100)/23 = 4.35 kg of air

similarly, 1 m^3 of oxygen is supplied by:

= (1x100)/21 = 4.76 m^3 of air

4. Molecular mass of air is taken as 28.94 g/mol.

5. The mass of any gas can be converted to its volume at certain T and P by using the gas equation, PV=nRT.

6. Minimum oxygen required = theoretical oxygen required – oxygen present in the fuel.

7. Minimum oxygen required should be calculated on the basis of complete combustion

8. In practice it is impossible to obtain complete combustion under stoichiometric conditions.

9. Incomplete combustion is a waste of energy and it leads to the formation of carbon monoxide, an extremely toxic gas, in the products. So, excess air is used

10. Excess air is expressed as a percentage increase over the stoichiometric requirement and is defined by:

$$\%\,Excess\ air = \frac{Actual\ air\ used - Theoritical\ air}{Theoritical\ air} \text{X}\,100$$

Excess air will always reduce the efficiency of a combustion system.

11. Hydrogen, present in the combined form (as H_2O) is a non combustible substance and does not take part in combustion. The rest of hydrogen, called **available hydrogen only takes part in the combustion reaction.**

- As, 1 part of hydrogen combines chemically with 8 parts by mass of oxygen to form water, the
- **Available hydrogen = mass of hydrogen – (mass of oxygen/8)**
- Theoretical amount of oxygen required for the complete combustion of 1 kg solid or liquid fuel:

  = {[(32/12) x C] + 8 [H – (O/8)] + S} kg

- Theoretical amount of air required for the complete combustion of 1 kg fuel:

  = (100/23) {[(32/12) x C] + 8 [H – (O/8)] + S} kg

(since, % of oxygen in air by mass is 23)

where, C, H , S and O are the masses of C, H, S and O respectively per kg of the fuel.

Steps-wise Calculations

1. Write the balanced chemical equations for various components present in the fuel.
2. Calculate the weight or volume of oxygen required by each one of them.
3. Find the total oxygen required by adding up the oxygen required by individual components and subtracting the amount of oxygen already present.
4. Convert the volume/ weight of oxygen into air

   Weight of air required = Total oxygen X 100/23 gm

   Volume of air required = Total oxygen X 100/21 m^3

7. Find out the air actually supplied by talking into consideration excess air.

8. To convert volume into weight use Avogadro's law.

Let y litre be the amount of air required…

$$1\ m^3 = 1000\ L$$

$$22.4\ L = 1\ mole = 28.94\ g\ of\ air$$

$$y\ L = 28.94/22.4\ X\ y\ gm$$

Numerical on Combustion

Q1. Calculate the mass of air to be supplied for the combustion of 1 kg of a fuel containing 75% carbon, 8% hydrogen and 3% oxygen, if 40% excess air is supplied.

Numerical on Combustion

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Constituent	Combustion Reaction	Amount (Kg)	Weight of Oxygen required (Kg)
Carbon	$C + O_2 \rightarrow CO_2$	0.75	0.75 x 32/12 = 2
Hydrogen	$H_2 + ½ O_2 \rightarrow H_2O$	0.08	0.08 x 16/2 = 0.64
Oxygen	----	0.03	----
Total oxygen = 2 + 0.64 – 0.03 = 2.61 kg			

(a) So minimum mass of air required for complete combustion = 2.61 kg X 100/23

= 11.35 kg

(b) Actual air supplied = 11.35 kg X 140/100

= 15.89 Kg

Q2. Calculate the weight and volume of air required for the combustion of 1 kg of carbon.

Numerical on Combustion

Q3. Determine the volume of air needed for complete combustion of one cubic meter of producer gas having the following composition by volume. H_2 = 30%, CO = 12%, CH_4 = 5% and N_2 = 50%.

Numerical on Combustion

Q4. Calculate the minimum amount of air required for complete combustion of 100 kg of the fuel containing C= 80%, H_2 = 6%, O_2 = 5%, S = 2% and rest N_2 by weight.

Numerical on Combustion

Q5. A gas has the following composition by volume: H_2 = 22%, CH_4= 4%, CO= 20%, CO_2 = 6%, O_2 = 3% and N_2 = 45%. If 25% excess air is used, find the weight of air actually supplied per m^3 of this gas.

Numerical on Combustion

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Q6. Calculate the volume of air at STP needed for the complete combustion of 5 L of CO.

Numerical on Combustion

Q7. The composition by volume of a certain fuel sample is H= 24%, CO= 6%, CO_2= 8%, CH_4=30%, C_2H_6=11%, C_2H_4=4.5%, C_4H_8=25%, O=2%, N= 12%. What theoretical amount of air would be required at 25°C and 750mm pressure for complete combustion of 1 m^3 of the fuel.

Numerical on Combustion

Q8. A sample of coal was found to have the following percentage composition: C= 75%, H= 5.2%, O= 12.1%, N= 3.2% and ash = 4.5%. Calculate the minimum air required for complete combustion of 1 kg of coal.

Numerical on Combustion

<u>Q9.</u> Calculate the volume of air at STP needed for the complete combustion of 1 Kg of methane.

Flue Gas Analysis

Flue gas is the gaseous product of combustion of fuels in ovens and furnaces. When combustion is complete, flue gas consists of carbon dioxide, water vapour, nitrogen and excess oxygen.

Analysis of flue gases give an idea about the complete or incomplete combustion process.

- If the analysis shows the presence of CO, it indicates incomplete combustion of the fuel or shortage of oxygen.
- If the analysis shows the presence of high percentage of oxygen, then it shows that though the combustion is complete but the supply of air is much in excess.
- If the analysis shows the presence of appreciable amounts of oxygen and carbon monoxide, it indicates that the combustion is irregular and non-uniform.

Flue Gas Analysis

Mass of dry flue gases formed should be calculated by balancing the carbon in the fuel and carbon in the flue gases.

- **Excess air** = Actual air – Total air
- **Total mass of N_2 in dry product of combustion**

  = N_2 in air supplied (in actual air) + N_2 present in fuel
- **Total mass of O_2 in dry product of combustion**

  = wt. of O_2 in excess air supplied
- **Excess oxygen** = excess air x 23% (by weight)

  or excess air x 21% (by volume)

Note- Air contains 21% oxygen and 79% nitrogen by volume and 23% oxygen and 77% nitrogen by weight.

Numerical

Q1. The percentage composition by mass of a sample of coal is C = 90, H_2 = 3.5, O_2 = 3.0, N_2 = 0.5, S = 0.5, the remaining being ash. Estimate the minimum mass of air required for the complete combustion of 1 kg of this fuel and the percentage composition of dry products of combustion.

Numerical

Q2. A gaseous fuel has the following composition by volume CH_4 = 25%, H_2 = 20%, C_2H_6= 16%, C_2H_4= 9.5%, butene= 2.5%, CO= 4%, CO_2 = 8%, N_2 = 12%, and O_2= 4%. Find the air required for perfect combustion of 1m^3 of this gas. If 50% excess air is used, find the volume analysis of dry products of combustion.

Numerical

Q3. A sample of coal contains C = 60%, H_2 = 4%, O_2 = 6%, N_2 = 2%, and ash= 28%. Calculate the percentage composition of dry products of combustion, assuming that 40% excess air is used.

Numerical

Q4. The percentage composition of coal was found to be as C = 54%, H_2 = 6.5%, O_2 = 3%, N_2 = 1.8%, moisture = 17.3% and remaining is ash. This coal on combustion of excess of air gave 21.5 kg of dry flue gases per kg of coal burnt. Calculate the percentage of excess air used for combustion.

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THANK YOU